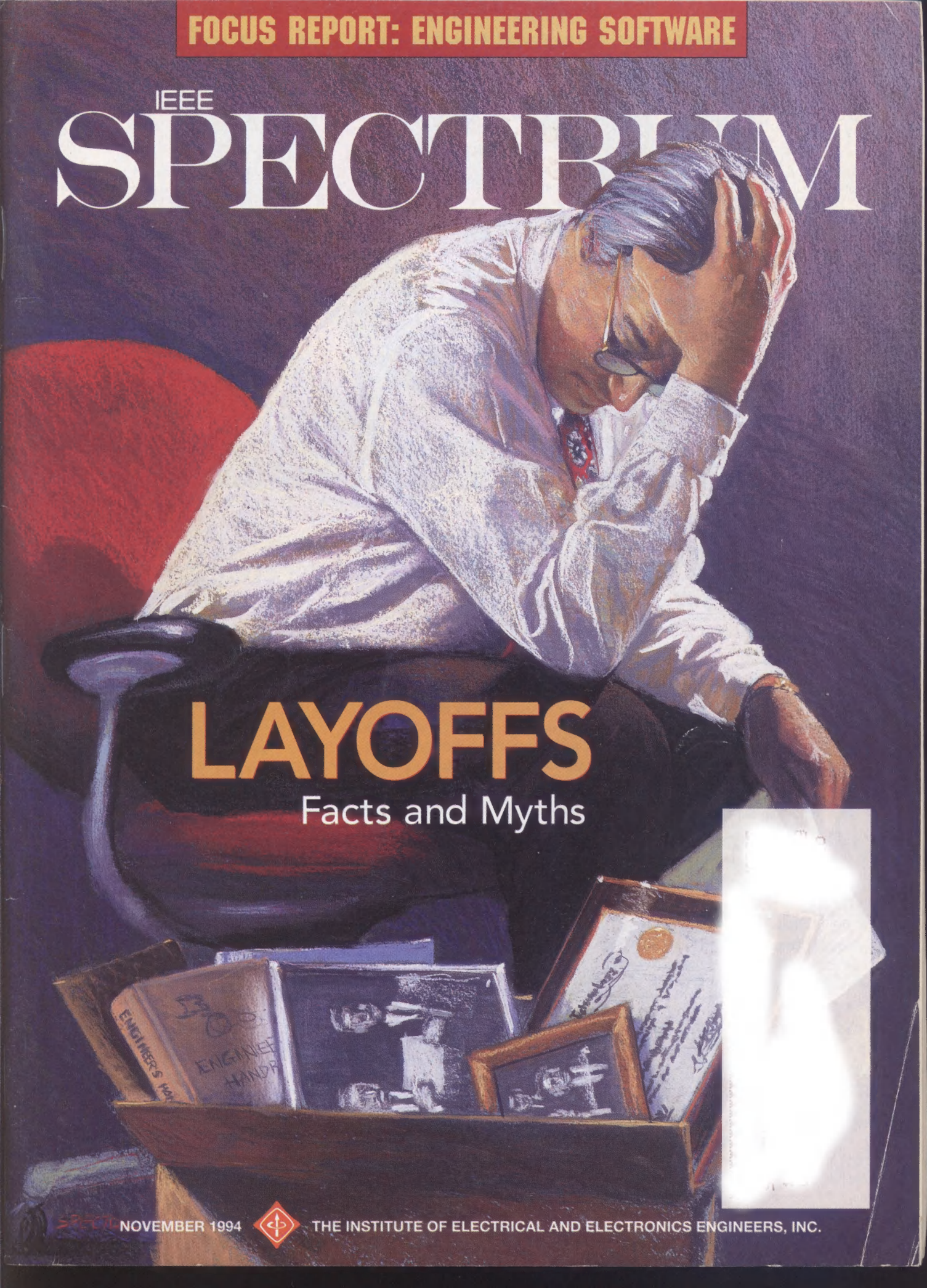
FOCUS REPORT: ENGINEERING SOFTWARE

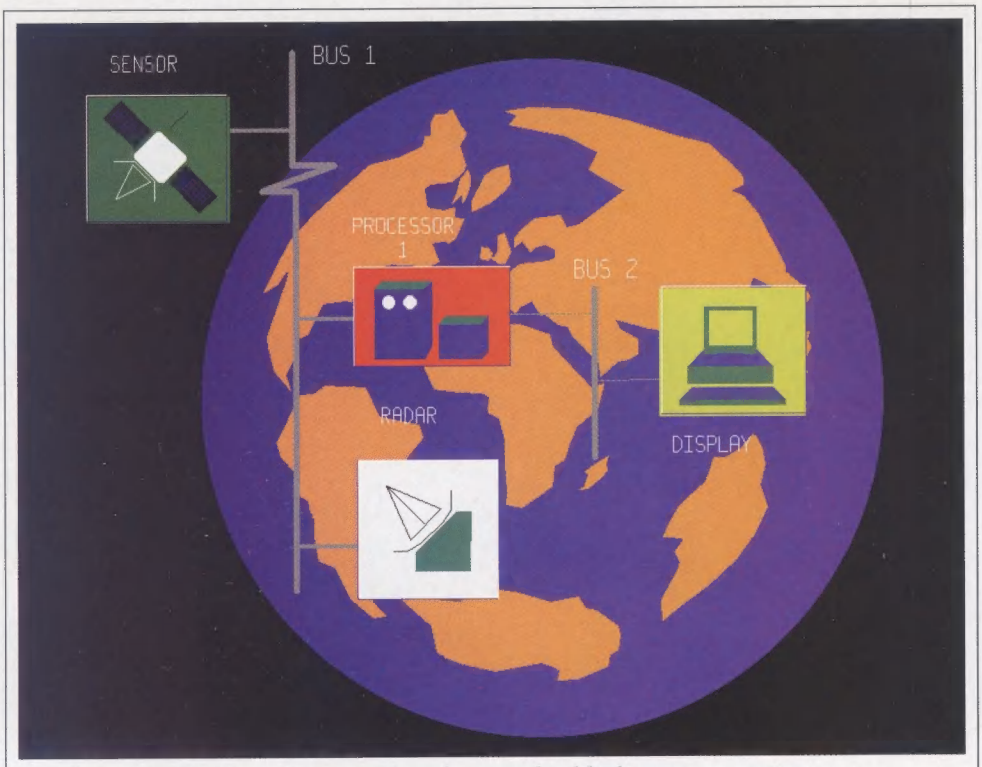
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LAYOFFS

Facts and Myths



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Newslog

SEP 9. Fuji Photo Film Co., Tokyo, said it had developed a 3.5-inch floppy disk with memory capacity of 100–200 MB—50 times that of conventional disks. Fuji said the disk, while storing about the same amount as magneto-optical disks, would be able to transfer data twice as fast—1 MB/s—and cost US $10 or less.

SEP 12. General Motors Corp.'s Hughes Aircraft Co., Los Angeles, said it would lay off 4400 more employees through 1995 and close its Fullerton, Calif., operations.

SEP 16. Researchers at the **French National Center for Scientific Research,** in Thiais, said they had developed an all-plastic, no-metal transistor. Using modern printing techniques, the group built up thin layers of various materials to construct paper-thin field-effect transistors, then employed plastic-like organic polymers and graphite inks to carry electricity. The development could lead to flexible computer screens that roll up like window shades.

SEP 16. RSA Data Security Inc., Redwood City, Calif., said its formula for coding information sent over computer networks had been anonymously circulated on Internet electronic bulletin boards. Experts said disclosure of the RC4 formula would not necessarily allow eavesdroppers to unscramble coded messages, but worldwide dissemination could compromise the system's long-term effectiveness.

SEP 19. Matsushita Electric Industrial Co., Tokyo, said it had demonstrated the basic principle of a computer memory capable of storing a thousand times as much as magnetic or optical disks. The technique, which uses an atomic force microscope, puts a single bit in a 10-nm-diameter circle—equivalent to storing a trillion bits in 1 cm^2.

SEP 19. Apple Computer Inc., Cupertino, Calif., said it would license its Power Macintosh operating-system software to other manufacturers, for the first time allowing them to produce Mac clones. Apple said it had defined its own platform, the Mac reduced-instruction-set computing architecture (MRA), which licensees will build to.

SEP 20. Groupe Bull SA, the French state-owned computer manufacturer, announced it would sell part of its U.S. and international services activities to **Wang Laboratories Inc.,** Lowell, Mass., for $160 million. Bull will take a 5 percent stake in Wang and a seat on its board. Wang will take over Bull's U.S. field services unit, all its operations in Canada, Mexico, Australia, and New Zealand, and its Washington, D.C.-based systems-integration business.

SEP 20. The space shuttle Discovery and its six astronauts ended an 11-day mission, during which two astronauts undertook the first untethered spacewalk in 10 years and tried out NASA's new $7 million jet pack, a life preserver for future space station crews.

SEP 21. NEC Corp., Tokyo, said it had selected Livingston, Scotland, as the site for a new $800 million semiconductor manufacturing plant. NEC said it chose Scotland to balance its plants in the United States and Japan and because European demand for chips is high.

SEP 22. Northrop Grumman Corp., Bethpage, N.Y., said it would reduce its 47 500 workforce by 8650 over the next 15 months in southern California, Long Island, N.Y., and Texas. The reductions reflect consolidation in the wake of the merger of Northrop Corp. and Grumman Corp. earlier this year.

SEP 23. The **German Parliament** gave final approval to a bill that would allow the world's first magnetic levitation train into long-distance service. Called Transrapid, the train in demonstrations has clocked the world speed record for trains—450 km/h. The Government agreed to pay $3.5 billion of the $5.6 billion cost needed in a 10-year plan to link Berlin and Hamburg. The 270-km ride, which now takes nearly 13 hours, would last 66 minutes.

SEP 23. China's State Bureau of Technical Supervision said it had issued national standards for the Chinese versions of MS-DOS to standardize the country's PCs. The standards are to go into effect on April 4. **Microsoft Corp.,** Redmond, Wash., said it had signed a contract with China's largest computer manufacturer, **Beijing Legend Group,** to develop a standard Chinese version of MS-DOS.

SEP 26. Moore Corp., Toronto, and **Electronic Data Systems Corp.,** Dallas, said they had signed reciprocal 10-year agreements together valued at over $1 billion. Under the terms of the pacts, Moore will handle all of EDS' forms and commercial printing requirements, and EDS will provide Moore with information technology support.

SEP 29. Toshiba Corp., Tokyo, said it had agreed to use **IBM Corp.**'s PowerPC microprocessor. Toshiba gains the unlimited right to use the PowerPC in any of its products, to design its own versions of the PowerPC, and to license and modify chip designs from IBM or its partner **Motorola Inc.,** Schaumburg, Ill. Toshiba is the first of the world's top PC manufacturers outside IBM and its partners Motorola and Apple Computer to adopt the PowerPC for future products.

OCT 3. Pacific Scientific Co., Newport Beach, Calif., said it had developed a possible fluorescent replacement for three-way household incandescent bulbs. The Solium prototype is a screw-in fluorescent system with electronic dimmers built into its base for adjusting light between 30 W and 150 W.

OCT 3. India's Communications Ministry said eight companies had been selected to run cellular services in India's four biggest cities—Bombay, New Delhi, Calcutta, and Madras. The companies, all of which have joint ventures with major international phone carriers, are expected to offer the services by next April.

OCT 4. Motorola Inc., Schaumburg, Ill., announced it would start manufacturing PCs, workstations, and computer servers using the PowerPC chip it co-developed with IBM and Apple Computer. The computers are to be resold to about 20 to 30 manufacturers and resellers.

OCT 4. MCI Communications Corp., Washington, D.C., said it had asked regulators in five states for permission to compete with the Baby Bells' local phone service. MCI filed—in Illinois, Maryland, Michigan, Pennsylvania, and Washington—just a few days after **British Telecommunications PLC** had completed its 20 percent purchase of the company.

OCT 5. Sematech Inc., Austin, Texas, announced a plan to wean itself from its $90 million annual Federal appropriation, which comes through the Department of Defense. The consortium said member companies after fiscal 1997 will continue supplying their annual $90 million for semiconductor research, but that Sematech will compete for Federal research grants to replace the congressional outlay.

Preview:

NOV 8–12. Electronica 94, the 16th international trade fair for electronic components and assemblies, will be held at the Munich Trade Fair Center in Germany. For details, call (49+89) 51070; fax, (49+89) 5107 506.

Sally Cahur

NOVEMBER1994 VOLUME 31 NUMBER 11

IEEE SPECTRUM

SPECIAL REPORT

16 Engineering layoffs: facts and myths

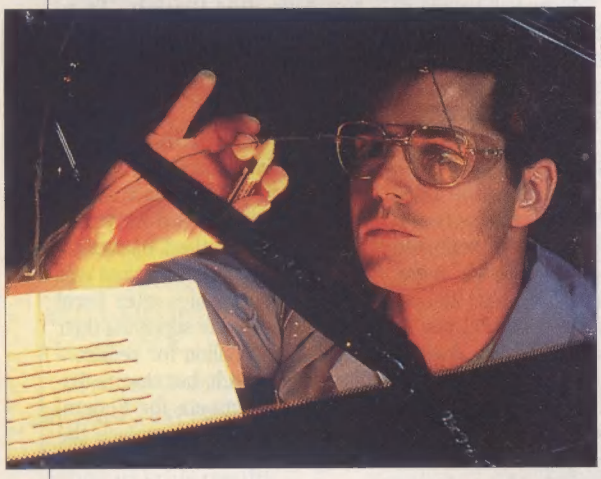
By TRUDY E. BELL

Downsizing seems to be unending—hitting even engineers in "hot" specialties, with a distinguished record, and who have kept themselves technically current. Spectrum spoke with former Mitre Corp. communications engineer Jack Liverman [right] and several other individuals in a similar position about what they have undergone.



Marc Bondarenko/Gamma Liaison

PERSPECTIVE



Toyota Technical Center, USA, Inc.

26 Foreign R&D on U.S. soil

By MANUEL G. SERAPIO JR. and DONALD H. DALTON

Non-U.S. companies have been increasing their R&D activity in the United States, as shown in a study of over 50 of those companies. Here, at Kobe Steel USA Inc.'s Applied Electronics Center in Palo Alto, Calif.,researchers are measuring electrical and magnetic properties of sputtered rigid-disk media.

PROFESSION

96 Taking charge of your career

By JOHN A. HOSCHETTE

Steering your career in the direction you want takes more foresight and planning, not to mention on-the-job assignments, than many engineers realize.

FOCUS REPORT

SOFTWARE

Engineers have a wide choice of software for mathematical calculations, visualizing data [photo, right], and designing with field-programmable gate arrays (FPGAs). New features and trends are highlighted.

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By GADI KAPLAN

35 Mathematical power tools

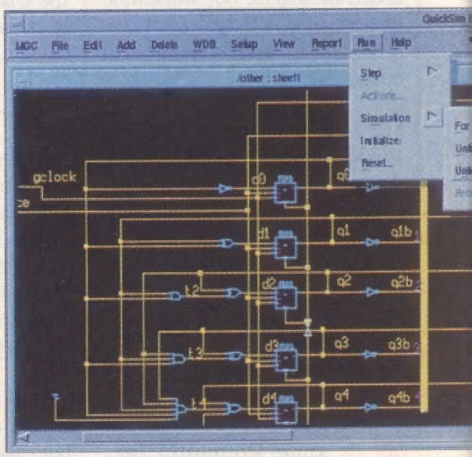
By ALFRED RIDDLE

Anywhere from 700 to 3000 functions can be handled by a wealth of quality software packages adorned with two- and three-dimensional plotting capabilities.

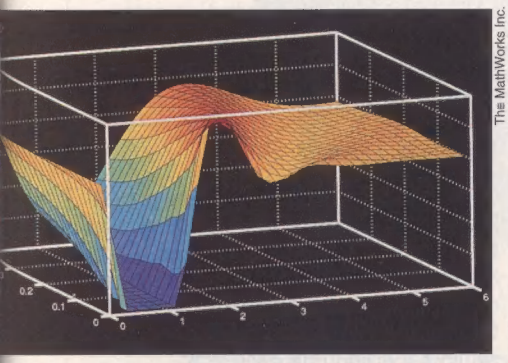
48 Visualization: the look of reality

By RICHARD S. GALLAGHER

In vector and tensor fields a single point must represent numerous variables, yet software research has devised clear and comprehensive ways of displaying them.



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57 From 3-D rendering to programmability

By KEN KORNBLUH

Engineers and scientists have never had more capable–or more numerous–packages for analyzing and viewing data in a wide range of disciplines.

84 Beyond the half-micrometer mark

By GYANENDRA TIWARY

To cope with the rapidly shrinking dimensions of chip features, new IC design tools are being developed to aid in power and timing analysis and in the modeling of second-order effects.

88 Tools to speed FPGA development

By BRADLY K. FAWCETT

Greater portability, improved support, and higher integration are virtues of the latest tools [see example at left] for designing, simulating, and implementing field-programmable gate arrays.


Mentor Graphics Corp.

Cover: A pastel drawing by Joel Spector portrays the human side of layoffs—the despair of an engineer whose job is being eliminated. Packed in the box beside him are his diploma, along with photographs of him receiving awards for his work at presentation ceremonies. But he is not alone, nor without recourse. See p. 16.

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POSTMASTER: Please send address changes to IEEE Spectrum, c/o Coding Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855. Second Class postage paid at New York, NY, and additional mailing offices. Canadian GST #125634188.

Printed at 8649 Hacks Cross Rd., Olive Branch, MS 38654, U.S.A.

IEEE Spectrum is a member of the Audit Bureau of Circulations, the Magazine Publishers of America, and the Society of National Association Publications.

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HEADQUARTERS: New York City, 212-705-7555
BUREAUS: WASHINGTON, D.C., John A. Adam, 202-544-3790; *SAN FRANCISCO,* Tekla S. Perry, 415-328-7570

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EDITOR EMERITUS: Donald Christiansen

EDITORS BY E-MAIL:

John A. Adam	j.adam@ieee.org
Trudy E. Bell	t.bell@ieee.org
Richard Comerford	r.comerford@ieee.org
Linda Geppert	l.geppert@ieee.org
Gadi Kaplan	g.kaplan@ieee.org
Tekla S. Perry	t.perry@ieee.org
Michael J. Riezenman	m.riezenman@ieee.org
Alfred Rosenblatt	a.rosenblatt@ieee.org
Murray Slovick	m.slovick@ieee.org
Glenn Zorpette	g.zorpette@ieee.org

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Forum

Cardboard suspect

It was amusing that an analysis of a Walkman in "Recipe for recycling" [August, pp. 22–24] showed over 70 percent of its composition to be cardboard and waste.

Seriously, though, I assume that cardboard is a British term for circuit board. Is that correct?

Could the authors tell us briefly how circuit boards are processed? Are the boards shredded and the metals extracted chemically?

Fran Hanchek
Eden Prairie, Minn.

Author Michael B. Biddle replies: Yes, the Walkman recycle stream truly is made up of a large amount of cardboard and other packaging waste. Products in this particular recycle stream are returned in many cases from manufacturing waste, still in their original containers, and then shipped in large cardboard boxes that must be recycled. In this case, the packaging does indeed represent a significant portion of the stream.

Circuit boards are typically processed thermally, where the organic material is burned away from the metals. They may also be processed chemically, where the metals are stripped from the organic board material. Mechanical recovery processes are under investigation.

Tell me a story

As a person professionally devoted to the notion of interactivity, I have been struck by the lack of true engagement on the "net" and in other spaces. Gaming seems to consist mostly of Star Wars adaptations, or explorations of one kind or another that involve mouse-clicking with random reason. Edutainment? It seems like lackluster entertainment, and where education comes into it remains a mystery.

An instructional designer who has had the opportunity of working cross-culturally, I know that the concept of teaching by telling a story is universal. It provides a vehicle for imparting information, and it is a tested way of mentoring.

I also know that in doing business, the Japanese, and others, use "talk story" to communicate information *sotto voce* and to keep the listener from losing face. Where have all those story/mentoring models gone?

Why not use this flexible medium to mentor the next generation, on an international, cross-cultural level? The AI [artificial intelligence] folks should be able to help us out here. Capturing the wisdom of this generation and passing it on to the future in an electronic archive (a virtual library!) can only benefit our species, and assist us with our monumental planetary survival tasks.

Wisdom can be "key worded" and the learner can have access by computer to source material: lifetimes of experience, talents, history as it happened, the evolution of a law, and the various ways humans have solved the problems of survival—to say nothing of art, music, and so on. This situation is truly information available as needed, when needed.

A manager can send a new team member to the cultural/business history archive of the company; the team member selects information about the specific tasks that need to be accomplished. Trials and errors need not be repeated; building on past success can happen.

Students at any grade level can produce documentaries on whatever they are assigned or whatever interests them; the raw material, from many perspectives, is there for the assembly. Scripts developed, videos edited, experts "consulted," efforts of previous explorers in that particular realm can be obtained.

Sounds like involved, interactive learning to me. Is anyone working in these directions? Developing material in this way? Where are you? Who are you?

E. Winters
Berkeley, Calif.

Checking out the ozone

We see persistent concern over the possible health effects of electrical equipment, for example, the recent letter by Jerome H. Silverman [August, p. 6]. Sometimes this reaches absurd levels. J. Robert Ashley treats the question in detail in the *IEEE Instrumentation & Measurement Society Newsletter* (Summer 1992), commenting that some of the claimed risk is comparable to that incurred "in nude moon bathing."

Still, there is some statistical evidence relating childhood leukemia to the presence of high-voltage transformers. Therefore, the point I made in several letters to the *I & M Newsletter* (Summer 1992, Fall 1992, Spring 1993) is worth repeating—namely, that a known toxic agent, ozone, which may be generated by certain electrical equipment, may be responsible and bears investigation.

At issue is not the background level of ozone due to atmospheric pollution, but the purely local level of ozone due to nearby electrical equipment. Examples include living downwind from a high-voltage line and indoor operation of universal motors (vacuum cleaners, malted milk mixers, and others, which sometimes evince the characteristic odor of ozone). If investigation confirms the hazard, remedies are available, including corona shields on high-voltage lines and the replacement of the notoriously sparking universal motor by an electronically driven high-speed induction motor.

Joseph M. Diamond
Brooklyn, N.Y.

What's in a name?

The article "Mechatronics fills the breach" [August, pp. 46–49] stated that "Following the lead of Japan and Europe, the United States is making headway in an engineering discipline few have heard of—mechatronics." I must take issue with this somewhat head-in-the-sand view.

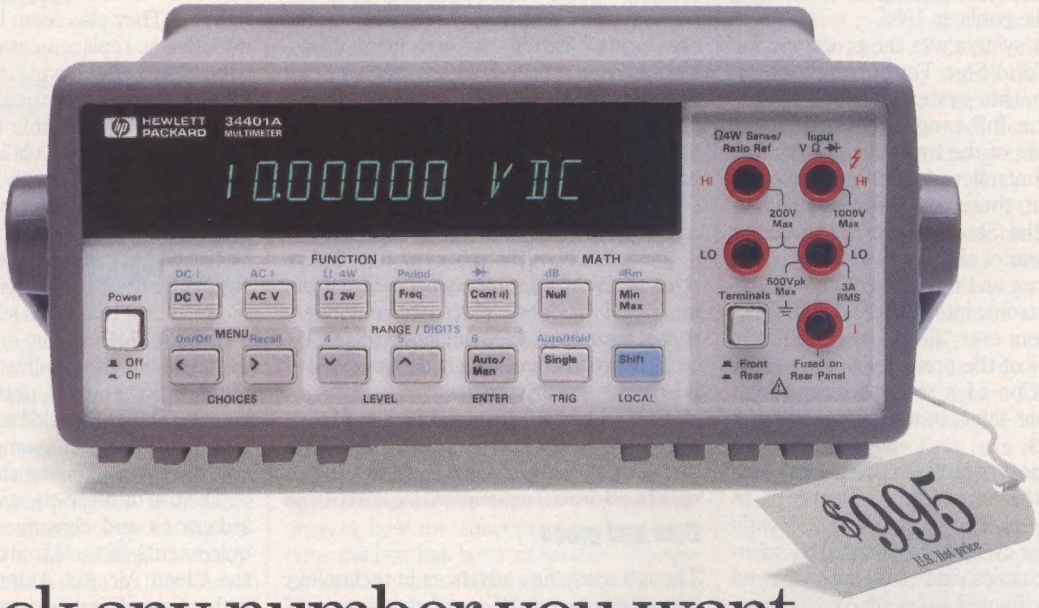
What is defined as "mechatronics" appears to be nothing more than a fancy name applied to systems engineering. For example, in 1959 Cal Tech JPL assembled a "Concurrent Engineering" team to design and build the guidance system for the Ranger spacecraft and its Atlas Centaur launch vehicle. That guidance system had to drive the dynamics of the Atlas and Centaur autopilot systems and flight dynamics.

Within that team, I was the flight sequencer controller engineer. I was given full responsibility for the design of the controller system. That design responsibility included functional specifications, electronic design, packaging (space flight and launch), and fail-safe firmware.

The flight controller design used multiaperture ferrite core logic. Core-based systems had never successfully flown in space before. The design required the use of a low-frequency, precision–crystal-controlled oscillator. In those days the low-frequency crystals were large and would not withstand the launch environment of the Atlas rocket. Using "mechatronic" designs, I was able to resolve the dynamics of the crystal mounting structure, the needs of the thermostatic control, the thermodynamic lead/lag requirements, and the electronic stability requirements into a practical system. (By the way, the controller is included in the Smithsonian Air and Space Museum exhibit of the evolution of computers in space.)

A more dramatic demonstration of the art of mechatronics right here in the United States was the development of the Tour-

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Forum

Of-The-Universe project. Tour-Of-The-Universe was the world's first six-axis flight-simulator–based amusement ride. The Tour project was designed in 1984 and opened to the public in 1985.

The Tour system was the prototype for the Disneyland Star Tours simulator attraction. In this system we had to understand the full range of working and failure modes of the hydraulic system and the servo controllers for the motion base. Beyond that there was the dynamic interface of the Show Controller PLC, the first six-channel all-digital sound system, video systems, and the first computer-controlled, electronic intermittent, 70mm projection system ever "flown" in a simulator. The success of the project was a result of the application of a mechatronic design process. I was the systems engineer on the Tour project.

For the most part, the entire group of engineers in the amusement industry is, to one degree or another, mechatronically oriented. The dynamics of hydraulics, pneumatics, mechanics, and electronics allowed animatronic figures to become part of our leisure life. Many of the modern midway rides, from giant Ferris wheels and roller coasters to kamikazes and flying carpets, are the result of mechatronic design. From haunted mansions to back-to-the-future, mechatronics is at work. Making the technology transparent to the riders is also part of the amusement ride engineer's mechatronic art.

The ability to add computer modeling to our bag of tricks is going to make more engineers comfortable with mechatronics. To say mechatronics, in one form or another, did not exist here would be like saying U.S. engineers are so trapped by tunnel vision that they cannot see beyond some narrowly defined niche of a particular narrow field of engineering. I have been a *mechatronic* engineer for a long time, and I am proud of the accomplishments of my fellow U.S. mechatronic engineers.

David L. Collins
Newbury Park, Calif.

Let me be your guide

The "Nonlinear non sequitur" item in Technically Speaking [August, p. 54] shows a distressing ignorance of Japanese (or, at least, Tokyo) addresses.

Although no one would argue that Tokyo addresses are as deterministic as, for example, those of Salt Lake City (to take an extreme case), they are in many ways at least as comprehensible as those in Paris. Although house numbers may well at one time have been assigned in the order houses were built, many of the address peculiarities were rationalized in the 1960s by a commission chaired by Matsukata Saburo.

You will now find that house numbers ascend monotonically as you walk around the block (*banchi*). Moreover, these blocks are also numbered sequentially in a reasonable two-dimensional array. The blocks are located within *cho-me*, again unambiguously numbered within each of the named districts (for example, Minami Azabu) in Tokyo. Finally, each district is situated in one of the 23 *ku*, roughly comparable to New York boroughs or Paris arrondissements. Trust me—give me an address and I will show you the way.

Incidentally, although very few Tokyo streets have names, nearly every important intersection does; electrical engineers should have no problem understanding a coordinate system based on node-names. That is how the taxi drivers do it.

Robert A. Myers
Thornwood, N.Y.

Cool and green

Though many fine advances in technology were reported in "'Green' refrigerators" [August, pp. 25–30], there was no discussion of a topic that I expected to read about.

On nearly all domestic and commercial refrigerators the doors open outward, toward the user. Each time the door opens, a mass of cold air falls out of the refrigerator onto the floor. How does this regular (predictable and expected) loss of cool air compare to the other efficiencies that are being advanced?

I expected to read a plea for a new generation of refrigerators that are like chest-type freezers, and like refrigerators and freezers on sailboats—that is, the lid opens upward. With this design nearly all of the cool air stays inside the chest.

Such a refrigerator design would, of course, affect the design and operation of the kitchen. Besides, where would we hang our children's pictures and our notes!

Michael Hajny
Charleston, S.C.

The article did not mention fluoro-iodocarbons (FICs) as CFC replacements, perhaps because the author was unaware of a new family of cost-competitive fluoro-iodocarbons that have the potential to be drop-in replacements for many existing applications using the popular CFC-12.

A fluoro-iodocarbon is a molecule that contains fluorine, iodine, and carbon. Unlike other alternative chemicals developed to date, these FICs, alone and in blends, have low toxicity, clean evaporation, excellent performance, low environmental impact, are *noncorrosive* and *nonflammable*, and will, in many cases, *require no modifications of existing equipment* for proper performance. These new chemicals also have outstanding physical properties and fire-extinguishing abilities comparable to Halon's.

FICs appear to be prime candidates to replace Halon 1211 as streaming agents and Halon 1301 as flooding agents for fire-fighting. They also seem likely to be highly effective as replacements for refrigerants, solvents, foam-blowing agents, and nonflammable aerosol propellants. A blend of FIC appears to be able to reduce, if not eliminate, the oil insolubility and lubrication problems associated with HFC-134A.

Because FICs will provide equal, and in some cases superior, performance as drop-in replacements for existing substances, significant costs of modifying existing equipment to new materials such as HFC-134A and HCFC-141b will be avoided. Pressure-vapor information indicates that FICs are more efficient than previous CFC compounds. This fact could be utilized to reduce electrical power consumption for further cost and environmental savings.

The use of these chemicals will help U.S. industries and consumers meet the requirements of the Montreal Protocol and the Clean Air Act Amendments of 1990 without sacrificing performance. Interested readers may refer to "Fluoroiodocarbons as Halon Replacements" and "A New Class of High-Performance, Environmentally Sound Refrigerants," papers that were delivered at the International CFC and Halon Alternatives Conference in Washington, D.C., Oct. 20–22, 1993.

Craig B. Lankford
Oklahoma City, Okla.

So much to learn...

Simon R. Burne's letter about the Faraday £20 banknote [September, p. 6] calls to mind a letter in the Education section of one of the United Kingdom's heavier papers, *The Guardian*. In 1991, when the subject of the new note was announced, a schoolboy wrote complaining that Shakespeare, who was on the old note, was to be replaced by "a little-known electrician"!

Dick Jones
London, United Kingdom

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Books

Tilting at a tired myth

Ronald R. Kline

Does Technology Drive History? The Dilemma of Technological Determinism. *Ed. Merritt Roe Smith and Leo Marx, MIT Press, Cambridge, Mass., 1994, 280 pp., $35 ($16.95 paperback).*



Although intellectuals have debated it with vigor since Karl Marx's time, an intuitive sense of technological determinism seems an integral part of U.S. culture. Again and again newspapers, magazines, and electronic media convey the message that technological change creates social progress. Even those who have denounced technology for degrading the environment and causing unemployment and other ills reinforce the idea of technological determinism by their very acceptance of it as a powerful social force.

So prevalent is this belief that the theme of the 1933 Chicago World's Fair—"Science Finds, Industry Applies, Man Conforms"—would hardly seem out of place as a newspaper headline today, notwithstanding two decades of criticism by historians and sociologists of technology. This book is an excellent sampling of recent scholarship in the area, and the question it addresses with its collection of essays takes direct aim at the complex relationship between technology and society.

The book is based on a conference held at the Massachusetts Institute of Technology (MIT) in late 1989. It consists of a general introduction by the editors; 12 essays by scholars in the fields of history, political science, literary criticism, and economics; helpful introductions to each essay; and concluding remarks by a senior historian of technology.

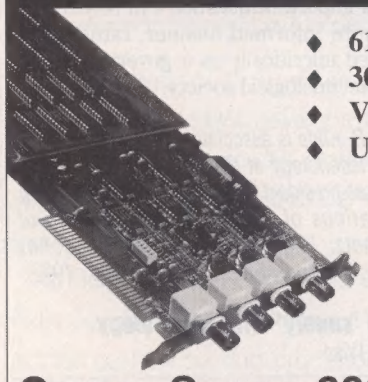
The essays present quite a variety of approaches to the topic. Some authors analyze how the concept of technological determinism has been utilized by scholars and politicians. Others explain why the concept has been so prevalent in U.S. culture. A third group (in my taxonomy) uses primarily case studies to answer the question, "Does technology drive history?"

The first type of approach is represented by four essays. Political scientist Bruce Bimber persuasively argues that Karl Marx was not a technological determinist, mainly because Marx's theory of history does not maintain that social changes are governed by laws based on technology. Bimber also sets up a useful taxonomy of three types of technological deterministic accounts.

In the second of the four treatments, historian Philip Scranton develops a postmodern critique of deterministic master narratives; instead, he argues for a consideration of local determinism and reciprocal power relations. Another historian, John Staudenmaier, drawing on his wide knowledge of scholarship in this field, asks his colleagues to consider more fully the context of technology and to refrain from writing internalistic accounts of technology's forward march.

Rosalind Williams, a professor in the writing program at MIT, takes a much different tack. She reminds us of the arresting fact that those in power have often created technological determinism by using technol-

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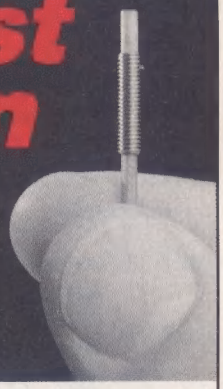
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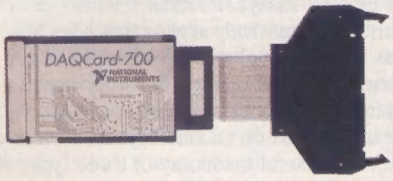
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Books

ogy to control people. She makes another good observation by describing the masculine bias evident in both the discourse and practice of technological determinism.

The essays on the history of this concept—all of which are by historians—will probably be of more interest to nonspecialists. After sketching the origins and early history of technocratic beliefs in the United States, Merritt Roe Smith makes the important point that 20th-century advertisers have helped to infuse U.S. culture with the Enlightenment idea of technology as an instrument and symbol of social progress.

Michael Smith does a marvelous job of contrasting the images of technological progress in a 19th-century lithograph and a *Popular Science* magazine article from the 1950s. The lithograph symbolized technological progress as a steam-engine train smoothly passing in harmony through the landscape and nature; the *Popular Science* drawing depicted a veritable explosion of ever-modernizing goods and consumer items, leading toward a science-fiction–like future of rockets, nuclear-powered cars, and the like. Leo Marx makes an intriguing case that the replacement of the craft phrase "mechanic arts" by the more abstract, mechanistic, and reified term "technology" signaled a more deterministic way of thinking about artifacts and culture—a view that led to disenchantment with technology in the postmodern era.

The essays based mainly on case studies and other empirical evidence span a wide spectrum in time and subject matter. The editors have reprinted economist Robert Heilbroner's classic 1967 article, "Do Machines Make History," and add a new essay by him. It reaffirms a "soft" version of technological determinism in an argument that classifies technology as a "background element" of capitalistic economies.

Historian Richard Bulliet rebuts Heilbroner by citing three counterexamples. Block printing, harnessing of draft animals, and wheeled transport, all "potentially transformative technologies," were not adopted in pre-capitalist Islamic countries because of what he calls "social filters" related to class, lifestyle, and ethnicity.

Historian Peter Perdue contrasts Lynn White's classic tale of technological determinism in medieval agriculture with two studies that discuss many factors other than technology: one deals with 18th-century Russian agriculture and the other with Chinese agriculture since the 14th century. Perdue concludes that technology constrains, rather than determines.

Two other historians, Thomas Misa and Thomas Hughes, argue for a more interactive approach. Misa rightly says that historians need to devote as much attention to how technology shapes society as they do to how social groups shape technology. He tells such a story, from a middle manager's point of view, about how Andrew Carnegie resisted integrating his company vertically. The social factor in this case is the company's organizational structure.

Hughes, who has written extensively about the history of electric power networks, uses the example of the holding company Electric Bond and Share to show how it both shaped society and was shaped by social groups. Positioning his concept of "technological momentum" midway between the doctrines of technological determinism and social construction of technology, he makes a strong case for variable social forces. They are more of a factor in the early stages of a sociotechnical system, he suggests, than in its mature stages, when a widespread system can determine social relations.

How, then, does the book answer the question in its title? Does technology drive history? While almost all the essays oppose technological determinism, the book's main strength is that it provides a variety of methodologies and examples for readers to use to (re)frame and answer this question. Best are the essays that help us understand the prevalence of the belief in technological determinism and the case studies that illustrate the contingent, messy complexity of technology when it is viewed as part of culture.

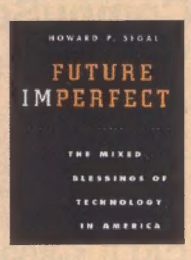
The book deserves a wide readership, so that its important question can be debated in a more informed manner, rather than accepted uncritically as a governing tenet of our technological society.

Ronald R. Kline is associate professor of the history of technology at Cornell University, Ithaca, N.Y., past-president of the IEEE Society on Social Implications of Technology, and author of Steinmetz: Engineer and Socialist (Johns Hopkins University Press, Baltimore, Md., 1992).

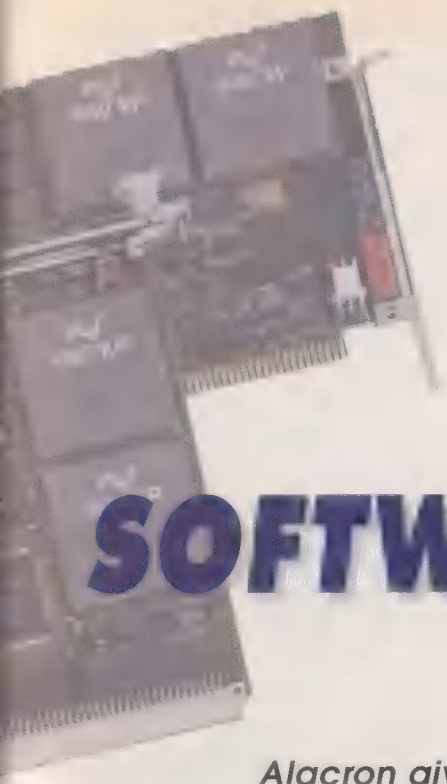
Living 'sanely' with technology

George Wise

Future Imperfect: the Mixed Blessings of Technology in America.
Howard Segal, University of Massachusetts Press, Amherst, 1994, 245 pp., $40 ($15.95 paperback).



The author of this book, a professor of history, has a reasonable and interesting thesis: that citizens of the United States can



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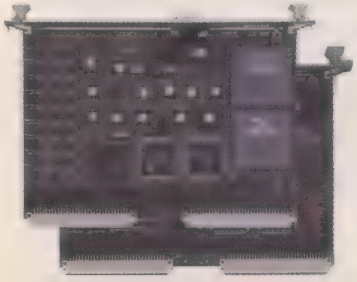
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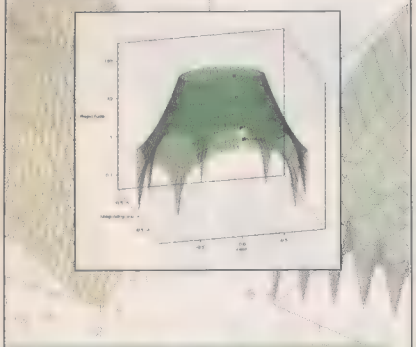
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Books

live "sanely and humanely" with technology if they abandon the quest after technology-based utopias, and instead concentrate on shaping a "middle landscape" that reconciles wilderness-lost with civilization-not-yet-achieved. He also writes clearly, in plain language that avoids the jargon of both high technology and professorial history.

In this book, however, he takes only partial advantage of these strengths. He is at his best in the chapter entitled "The Automobile and the Prospect of Technological Plateau." There, he uses the history of the automobile to illustrate why he views technology in the United States as a "mixed blessing."

Segal refutes the extreme views that see the automobile as the emblem of modernity, or, conversely, as an out-of-control beast gobbling up lives, resources, and landscape on the way to its inevitable and imminent doom. Instead, he sees the automobile as typical of the U.S. tendency to promote technological advances, "allowing Americans to achieve various changes without fundamentally altering their basic institutions and values."

The automobile has served to reconcile city and country (in the form of suburbia), agriculture and industry (by providing affordable cars to both farmer and factory worker), and even machine and nature (the Sunday drive in the country). In Segal's view, the automobile will best serve the United States in the 21st century, not by regaining its status as a vanguard of high tech, but by subsiding into the commonplace.

Segal's ideal is the "technological plateau," which he describes as "a society in which technology has become sufficiently advanced and widespread that equivalent attention can be given to achieving equally vital non-technological improvements: social, economic, cultural, political." Such a theme deserves a book-length treatment. It does not get one here.

Instead, Segal has strung together revisions of previously published articles. So rather than experiencing the unfolding implications of an idea, we bounce from the cultural insights of Leo Marx and Alexis de Tocqueville to a review of the exhibits at the Maine State Museum to a summary of a forgotten feminist utopia. All of this is presented at a second or third remove from the 20th-century high technology that is ostensibly the book's subject. Rather than talk technology, Segal talks about what some author said about technology, or about what some commentator said about what some author said about technology, or about what Segal thinks about what some commentator said about what some author said about technology.

Walt Whitman, after listening too long to a learned astronomer, felt an urge to go out and look at the stars. After reading too long from this book, one feels an urge to go out and kick a tire or boot up a computer. The U.S. infatuation with the promise of technology is best deflated not with scholarship but with other weapons. Dave Barry, a "happy nerd in cyberspace, where nobody can see my haircut," does it with humor. Wendell Berry, a tobacco farmer and poet who would replace tractors with horses, does it with indignation. Segal, in his concluding chapter, "High Tech and the Burden of History" falls flat trying to do it with lists.

He skewers some obvious targets: the prose of Alvin Toffler is portentously pretentious; Charlie Chaplin is almost as ludicrous a spokesman for IBM as Leonardo da Vinci is for Xerox; world fairs aren't what they used to be; the technological literacy movement has not yet become either technological or literate. He concludes with nine impenetrable ironies, the eighth of which is that the democratic rhetoric of advocates of technological literacy "does not quite mesh with the elitism inherent in both the major engineering schools and the prestigious liberal arts colleges that have nearly monopolized public and private funds for the New Liberal Arts." Conclusions that consist of lists, and excessive use of the word *irony*, are sure signs that a historian does not quite know what to say next.

At his best in this book, Segal has a great deal to say. One looks forward to another book in which he will say it.

George Wise is a communications specialist at the GE Research and Development Center in Schenectady, N.Y. He is the author of Willis R. Whitney, General Electric, and the Origins of American Industrial Research *(Columbia University Press, New York, 1985).*

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Recent books

Shop Floor Control Systems: From Design to Implementation. *Bauer, A., et al.*, Chapman & Hall, New York, 1994, 344 pp., $43.

Chaos in Wonderland: Visual Adventures in a Fractal World. *Pickover, Clifford A.*, St. Martin's Press, New York, 1994, 302 pp., $29.95, $41.50 (CAD).

Soft Computing: Fuzzy Logic, Neural Networks, and Distributed Artificial Intelligence. Eds. *Aminzadeh, Fred*, and *Jamshidi, Mohammad*, Prentice Hall, Englewood Cliffs, N.J., 1994, 301 pp., $65.

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Advanced Semiconductor Manufacturing Conference and Workshop (ED); Nov. 14–16; Hyatt Regency Hotel, Cambridge, Mass.; Margaret M. Kindling, SEMI, 2000 L St., N.W., Suite 200, Washington, DC 20036; 202-457-9584; fax, 202-659-8534.

Topical Conference on the Synthesis and Processing of Electronic Materials (ED); Nov. 14–16; San Francisco Hilton Hotel; Denise DeLuca, AIChE, 345 E. 47th St., New York, NY 10017; 212-705-7344; fax, 212-752-3297.

First Symposium on Operating Systems Design and Implementation (C); Nov. 14–18; Monterey Marriott, Monterey, Calif.; Judith DesHarnais, Usenix Association, 2560 9th St., Suite 215, Berkeley, CA 94710; 714-588-8649; e-mail, judy@usenix.org.

Singapore International Conference on Communications Systems (Singapore AP Chapter, Singapore COM-C, et al.); Nov. 14–18; The Westin Stamford, Stamford, Singapore; Jonnavan H. C. Hong, IEEE Singapore Section, #59D Science Park Dr., The Fleming, Singapore 0511; (65) 773 1141; fax, (65) 773 1142.

Supercomputing '94 (C); Nov. 14–18; Washington, D.C., Convention Center; SC '94 Office, Sherman Place, 125 South 3rd, Ames, IA 50010-6739; 800-854-1677; fax, 515-294-5204; e-mail, halstead@ameslab.gov.

Third Asian Test Symposium—ATS (C); Nov. 15–17; Nara Ken-New Public Hall, Nara, Japan; Hideo Fujiwara, Department of Information Processing, Graduate School of Information Science, Advanced Institute of Science and Technology, Nara 8916-4, Takayama-cho, Ikoma-shi, Nara 630-01, Japan; (81+7) 4372 5220; fax, (81+7) 4372 5219; e-mail, fujiwara@is.aist-nara.ac.jp.

Information Superhighway Seminar–Service Offerings and Applications (COM); Nov. 17; United Engineering Center, New York City; Jim Barbera, Metro Services Group, 333 Seventh Ave., New York, NY 10001; 212-594-7688; fax, 212-465-8877.

35th Annual Conference on Foundations of Computer Science (C); Nov. 20–22; Eldorado Hotel, Santa Fe, N.M.; Allan Borodin, Department of Computer Science, University of Toronto, Toronto, M5S 1A4, Canada; 416-978-6416; e-mail, borodin@cs.toronto.edu.

Topical Meeting on Optical Microwave Interactions (LEO, MTT, et al.); Nov. 21–23; Ile-de-France, Paris, France; Peter Herczfeld, Drexel University, Department of Electrical and Computer Engineering, Philadelphia, PA 19104; 215-895-2256; fax, 215-895-1695.

Global Telecommunications Conference—Globecom '94 (COM, OEB Section, et al.); Nov. 27–Dec. 1; Fairmont Hotel, San Francisco; Terry Kero, c/o Sprint, 1 Adrian Court, Burlingame, CA 94010; 415-375-4338; fax, 415-375-4079.

DECEMBER

Workshop on Applications of Computer Vision (C); Dec. 5–7; Holiday Inn, Sarasota, Fla.; Allen R. Hanson, Computer Science Department, Box 34610-LGRC, University of Massachusetts, Amherst, MA 01003-4610; 413-545-2746; fax, 413-545-1249; e-mail, hanson@cs.umass.edu.

Asia Pacific Conference on Circuits and Systems (CAS, SP, Taipei Section); Dec. 5–8; Grand Hotel, Taipei, Taiwan; Che-Ho Wei, Electronics Engineering Department, National Chiao Tung University, 1001 Ta-Hsueh Rd., Hsia Chu, Taiwan; (886+35) 723 283; fax, (886+35) 723 283.

International Conference on Industrial Technology—ICIT '94 (IA, IE, PEL, Beijing); Dec. 5–9; Zhudao Hotel, Guangzhou, China; C. J. Chen, AT&T Bell Laboratories, Room 2E514, Crawfords Corner Rd., Holmdel, NJ 07733; 201-949-0789; fax, 201-949-8040.

World Conference on Photovoltaic Energy Conversion (ED); Dec. 5–9; Hilton Waikoloa Village, Waikoloa, Hawaii; Dennis J. Flood, MS 302-1, Lewis Research Center, 21000 Brookpark Rd., Cleveland, OH 44135; 216-433-2303; fax, 216-433-6106.

Asia Pacific Microwave Conference—APMC '95 (MTT, T/MTT Chapter); Dec. 6–9; Nippon Convention Center, Chiba, Japan; Masami Akaike, c/o Realize Inc., Cosmos Hongo Building. 4-1-4 Hongo, Burkyo-ku Tokyo 113, Japan; (81+3) 3815 8590; fax, (81+3) 3815 8939.

Semiconductor Interface Specialists Conference (ED); Dec. 7–10; San Diego Hilton, California; Robert E. Stahlbush, IBM Thomas J. Watson Research Center, Room 29–113, Box 218, Yorktown Heights, NY 10598; 914-945-2837; fax, 914-945-2141.

Workshop on Mobile Computing Systems and Applications (C); Dec. 8–9; Dream Inn, Santa Cruz, Calif.; Darrell Long, Computer and Information Sciences, University of California, Santa Cruz, CA 95064; 408-459-2616; fax, 408-459-4829; e-mail, darrell@cse.ucsc.edu.

International Electron Devices Meeting (ED); Dec. 11–14; San Francisco Hilton and Towers; Melissa Widerkehr, Widerkehr and Associates, Suite 610, 1545 18th St., N.W., Washington, DC 20036; 202-986-1137; fax, 202-986-1139.

Winter Simulation Conference—WSC '94 (C, SMC); Dec. 11–14; Walt Disney Swan Hotel, Lake Buena Vista, Fla.; Deborah A. Sadowski, Systems Modeling Corp., 504 Beaver St., Sewickley, PA 15143; 412-741-3727; fax, 412-741-5635; e-mail, bonehead@mcimail.com.

International Symposium on Parallel Architectures, Algorithms and Networks (C); Dec. 14–16; Japan Advanced Institute of Science and Technology and International Hotel Kanazawa, Ishikawa, Japan; Frank Hsu, Department of CIS, JMH 340, Fordham University, 441 E. Fordham Rd., Bronx, NY 10458; 718-817-4482; fax, 718-817-4925; e-mail, hsu@murray.fordham.edu.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 80055; 908-562-3878; submit conferences for listing to: Ramona Foster, IEEE Spectrum, 345 E. 47th St., New York, NY 10017; 212-705-7305.

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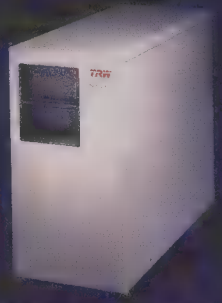
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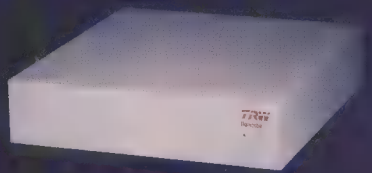


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33rd Conference on Decision and Control (CS); Dec. 14–16; Buena Vista Palace at Walt Disney World Village, Orlando, Fla.; M. K. Masten, Texas Instruments Inc., 2309 Northcrest, Plano, TX 75075; 214-995-7986; fax, 214-995-2770; e-mail, m.masten@ieee.org.

First International Joint Conference of the North American Fuzzy Information Processing Society—NAFIP/IFIS/NASA '94 (NN); Dec. 18–21; Sheraton Gunter Hotel, San Antonio, Texas; Uthra Venkatraman. Department of Computer Science, MS 3112, Texas A&M University, College Station, TX 77843-3112; 409-845-1870; fax, 409-847-8578.

Third International Workshop on Cellular Neural Networks and Their Applications—CNNA '94 (CAS, Region 8); Dec. 18–21; University La Sapienza, Rome, Italy; V. Cimagalli, Department of Electronic Engineering, La Sapienza University of Rome, via Eudossiana 18, Rome, Italy I-00184; (39+6) 4458 5836; fax, (39+6) 4742 647; e-mail, cima@tce.ing.uniromal.it.

International Conference on Parallel and Distributed Systems (C); Dec. 19–21; National Chiao Tung University, Heinchu, Taiwan; Lionel M. Ni, CS Department, Michigan State University, 714 Wells Hall, East Lansing, MI 48824-1027; 517-353-4386; fax, 517-336-1061; e-mail, ni@cps.su.edu.

First International Conference on Electronics, Circuits, and Systems—ICECS '94 (CAS); Dec. 19–22; Nile Hilton Hotel, Cairo, Egypt; Jenny Curry, Department of Electrical Engineering, Ohio State University, Columbus OH 43210; 614-292-3245; fax, 614-292-7596.

First International Conference on Software Testing, Reliability and Quality Assurance—STRQA '94 (Region 10, et al.); Dec. 21–22; Hotel Taj Palace, New Delhi, India; Aditya Mathur, Department of Computer Science, Purdue University, W. Lafayette, IN 47907; 317-494-6010; fax, 317-494-0739; e-mail, amp@cs.purdue.edu.

1995 JANUARY

Eighth International Conference on VLSI Design (C, CAS); Jan. 4–7; Hyatt Regency, New Delhi, India; Adit D. Singh, Department of Electronics Engineering, Auburn University, Auburn, AL 36849; 205-844-1847; fax, 205-844-1809; e-mail, adsingh@eng.auburn.edu.

Industrial Automation and Control—IA&C '95 (IA, et al.): Jan. 5–7; Krishna Oberoi Hotel, Hyderabad, India; E. Bhagiratha Rao, Engineering Staff, College of India, Khairatabad, Hyderabad 500004, India; (91+40) 229 666; fax, (91+40) 243 634.

International Conference on Industrial Automation and Control (IA, Hyderabad, India Chapter); Jan. 5–7; Krishna Oberoi Hotel, Hyderabad, India; E. Bhagiratha Rao, Engineering Staff, College of India, Khairatabad, Hyderabad 500-028, India; (91+40) 229 666; fax, (91+40) 242 634; e-mail, ebrao%engsci@uunet.in.

Broadband Multimedia Applications and Network Architectures (COM); Jan. 8–11; Loews Ventana Canyon Resort, Tucson, Ariz.; J. Keller, IEEE Communications Society, 345 East 47th St., New York, NY 10017-2394; 212-705-8248; fax, 212-705-7865.

(Continued on p. 12E6)

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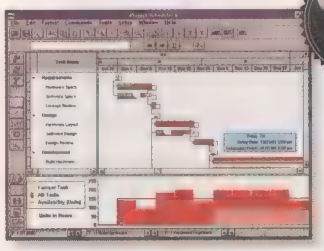
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Calendar

(Continued from p. 12E4)

10th Annual Battery Conference on Applications and Advances (AES, PEL); Jan. 10–12; California State University, Long Beach; Renee Madrid, Department of Electronics Engineering, California State University, 1250 Bellflower Blvd., Long Beach, CA 90840-8303; 310-985-4605; fax, 310-985-7561.

Brazilian School of Microelectronics (ED); Jan. 15–20; Cidade Universitaria, Recife, Brazil; Edval J.P. Santos, Department de Fisica, University Federal de Pernambuco, Cidade Universitaria, 50670–901 Recife PE, Brazil; (55+81) 271 01 11; fax, (55+81) 271 03 59.

Reliability and Maintainability Symposium—RAMS (R); Jan. 17–19; Washington Hilton, District of Columbia; V.R. Monshaw, Consulting Services, 1768 Lark Lane, Cherry Hill, NJ 08003; 609-428-2342.

Conference on Wafer Scale Integration—ICWSI (C, CPMT); Jan. 18–20; Fairmont Hotel, San Francisco; Glenn Chapman, School of Engineering Science, Simon Fraser University, Burnaby, BC V5A 156 Canada; 604-291-3814; fax, 604-291-4951; e-mail, glennc@cs.sfv.ca.

First Symposium on High Performance Computer Architecture (C); Jan. 23–26; Sheraton Inn, Raleigh, N.C.; Edward W. Davis, Department of Computer Science, North Carolina State University, Box 8206, Raleigh, NC 27695-8206; 919-515-7045; fax, 919-515-7896; e-mail, davis@adm.scc.ncsu.edu.

Power Engineering Society Winter Meeting (PE); Jan. 29–Feb. 2; New York Hilton and Towers, New York City; Frank E. Schink, 14 Middlebury Lane, Cranford, NJ 07016-1622; 908-276-8847.

Multi-Chip Module Conference—MCMC-95 (C, CAS, et al.); Jan. 31–Feb. 2; Cocoanut Grove, Santa Cruz, Calif.; Lisa Pascal, Department of Computer Engineering, University of California, Santa Cruz, CA 95064; 408-459-2263; fax, 408-459-4829; e-mail, lisa@cse.ucsc.edu.

FEBRUARY

16th Aerospace Applications Conference (AES); Feb. 4–11; Snowmass Village Conference Center, Aspen, Colo.; Sohrab Mobasser, Jet Propulsion Laboratory, MS 198–235, 4800 Oak Grove Drive., Pasadena, CA 91109; 818-354-4466; e-mail, Sohrab_Mobasser@ccmail.JPL.Nasa.Gov.

Digital Video Compression: Algorithms and Technologies (C, COM); Feb. 5–11; San Jose Convention Center, San Jose, Calif.; Donna M. Rode, SPIE, Box 10, Bellingham, WA 98227-0010; 206-676-3290; fax, 206-647-1445; e-mail, donnar@mom.spie.org.

Multimedia Computing and Networking (C, COM); Feb. 5–11; San Jose Convention Center, San Jose, Calif.; Donna M. Rode, SPIE, Box 10, Bellingham, WA 98227-0010; 206-676-3290; fax, 206-647-1445; e-mail, donnar@mom.spie.org.

11th Semiconductor Thermal Measurement and Management Symposium—Semitherm XI (CPMT); Feb. 7–9; Red Lion Inn, San Jose, Calif.; Vincent P. Manno, Department of Mechanical Engineering, Tufts University, Medford, MA 02155; 617-628-5000, ext. 2548; fax, 617-627-3819; e-mail, vmanno@pearl.tufts.edu.

Fifth Working Conference on Current Measurement (OE); Feb. 7–9; St.

(Continued on p. 12E10)

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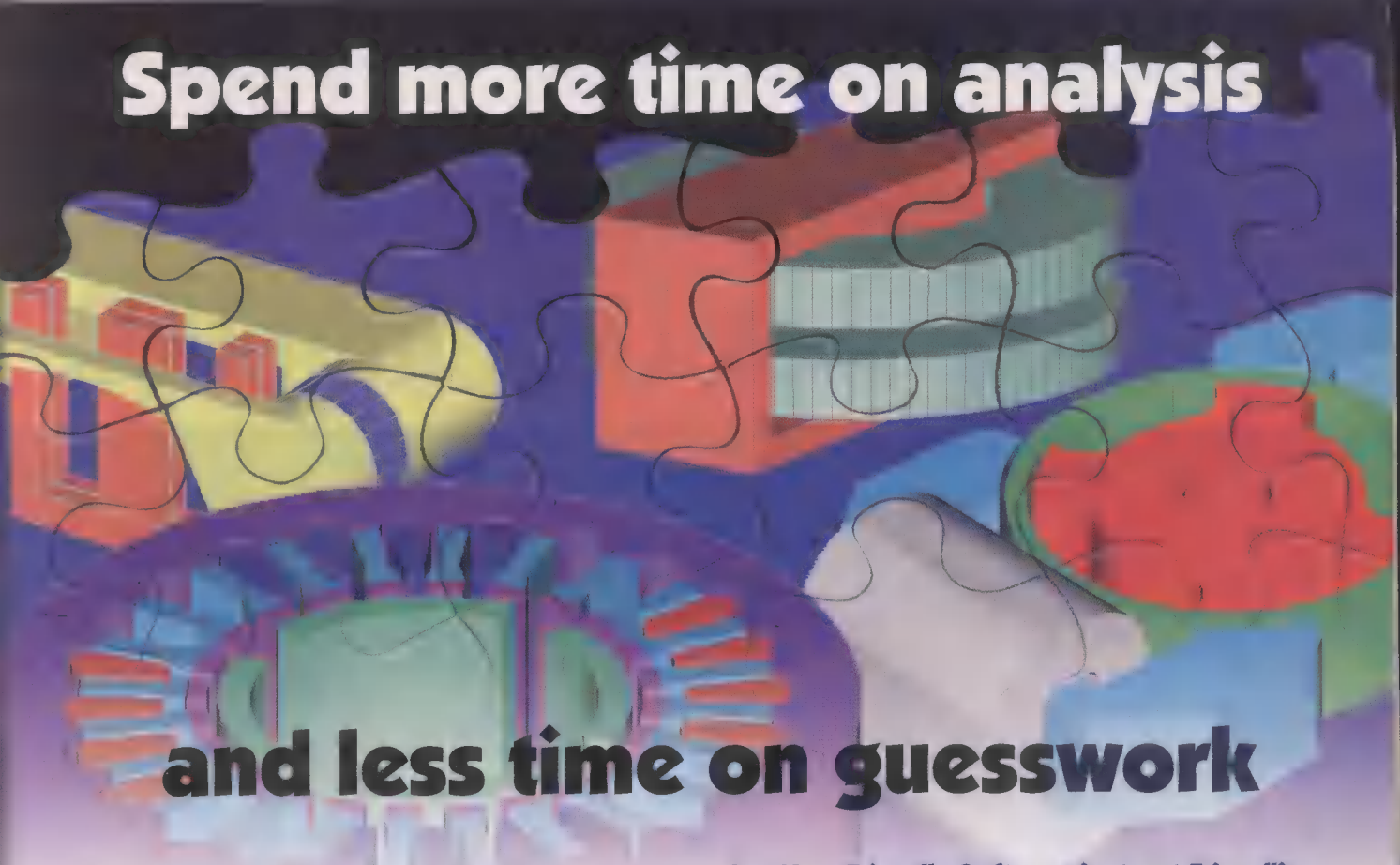
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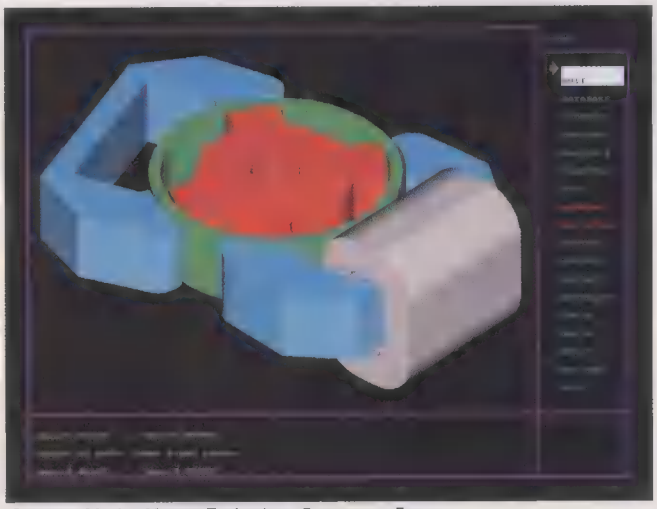
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DRAMs	16M/4M	3.3V	75mA/60mA	500µA/120µA	Reduced Switching Noise; Low SER; Self Refresh
Flash ICs	1M (x8)	5.0V(V_{pp}=12.0V)	15mA	50µA	Bulk Array; Power Up/Down Data Protection; Ind. Temp.; Volume Capacity
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DC-DC Converter	2.5V	1.3mA (typ.)	For Backlight Control; Output Short Protection; High Speed Switching (300KHz)
LCD Controller Driver	5.0V	-	Low Power, Dot Matrix LCD Control
Dual PLLs	1.8V	7.5mA (typ.)	410MHz; Various Power Save Modes
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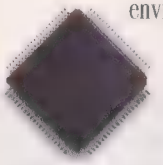
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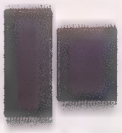
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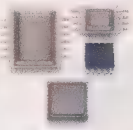
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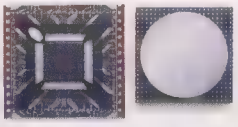
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Telecommunications Information Networking Architecture Workshop—TINA '95 (COM, Vic S/COM); Feb. 13–16; Sheraton Towers Hotel, Melbourne, Australia; Laura Kuzmicky, Telecom Australia, Level 36, 242 Exhibition St., Melbourne 3000, Australia; (61) 3634 4526; fax, (61) 3632 7416.

International Solid-State Circuits Conference—ISSCC '95 (SSC, et al.); Feb. 15–17; San Francisco Marriott; Diane S. Suiters, Courtesy Associates Inc., 655 15th Street, N.W., Suite 300, Washington, DC 20005; 202-639-4255; fax, 202-347-6109.

International Topical Symposium on Technologies for Wireless Applications (MTT); Feb. 21–23; Vancouver Trade and Convention Center, B.C., Canada; Peter W. Staecker, M/A-Com Inc., 100 Chelmsford St., Lowell, MA 01853-3294; 508-656-2607; fax, 508-656-2777; e-mail, p.staecker@ieee.org.

Second International Conference on Data Transmission—Advances in Data Communications, Technology and Applications (C, IT); Feb. 27–March 1; IEE Savoy Place, London; Jane Chopping, IEE, DT95 Secretariat, Conference Services, Savoy Place WC2R OBL, London, England; (44+71) 344 5477; fax, (44+71) 497 3633.

MARCH

Applied Power Electronics Conference and Exposition—APEC '95 (IA, PEL); March 5–9; Hyatt Regency Hotel, Dallas; Pam Wagner, Courtesy Associates, 655 15th St., N.W., Washington, DC 20005; 202-649-4090; fax, 202-347-6109.

Compcon Spring '95 (C); March 5–9; Stanford Court Hotel, San Francisco; Winfield Wilcke, HAL Computer Systems, 1315 Dell Ave., Campbell, CA 95008; 408-379-7000, ext. 1020; fax, 408-379-5022; e-mail, wilcke@hal.com.

11th International Conference on Data Engineering (C); March 6–10; Grand Hotel, Taipei, Taiwan; R. C. T. Lee, National Tsing Hua University, Hsinchu, 300, Taiwan; (886+35) 735 055; fax, (886+35) 722 713; e-mail, rctlee@nthu.edu.tw.

18th Convention of Electrical and Electronics Engineers (Israel Section); March 7–8; Kear Hamacabiah Hotel, Ramat-Gan, Israel; Ella Eisenberg, Faculty of Engineering, Tel-Aviv University, Tel Aviv 69978, Israel; (972+3) 640 7092; fax, (972+3) 642 3508; e-mail, ella@eng.tau.ac.il.

11th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility (EMC, et al.); March 7–9; Swiss Federal Institute of Technology, Zurich; Secretariat, IKT, ETH, Zentrum, CH-8092, Zurich, Switzerland; (41+1) 256 2788; fax, (41+1) 262 0943.

Southcon '95 (Region 3, Florida C); March 7–9; Greater Fort Lauderdale/-Broward County Convention Center, Fort Lauderdale, Fla.; Joan Carlisle, Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, CA 90045; 800-877-2668; fax, 310-641-5117.

Ultrafast Electronics and Optoelectronics Topical Meeting (ED); March

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13–17; Dana Point Resort, Dana Point, Calif.; Ellen Murphy, Optical Society, 2010 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-416-1995; fax, 202-416-6100.

International Conference on Computer Applications in Engineering and Medicine (C); March 15–17; University Place Hotel, Indianapolis, Ind.; Mohamed El-Sharkawy, Department of Electronics Engineering, Purdue University, 723 W. Michigan St., Indianapolis, IN 46202; 317-274-4559; fax, 317-274-4493; e-mail, elshark@etsun.engr.iupui.edu.

National Radio Science Conference (ED); March 21–23; Alexandria University, Alexandria, Egypt; Ibrahim A. Salem, 17 Elqouba St., 3, Roxy Heliopolis, Cairo-11341, Egypt; (20+2) 258 0256; fax, (20+2) 349 8217.

International Conference on Microelectronic Test Structures (ED); March 23–25; New Public Hall, Nara, Japan; Loren W. Linholm, National Institute of Standards and Technology, B-360 Technical Building, Gaithersburg, MD 20899; 301-975-2052; fax, 301-948-4081; e-mail, linholm@sed.eeel.nist.gov.

Seventh Workshop on Local and Metropolitan Area Networks (COM); March 26–29; Hawk's Cay Resort and Marina, Duck Key, Fla.; Yoram Ofek, IBM Thomas J. Watson Research Center, Box 704, Yorktown Heights, NY 10598; 914-784-6205.

Interpack '95: Towards Failure Free, Low Cost Electronic Packaging (CPMT); March 26–30; Westin Maui, Lahaina, Hawaii; Avram Bar-Cohen, Department of Mechanical Engineering, University of Minnesota, 111 Church St., S.E., Minneapolis, MN 55455; 612-626-7244; fax, 612-624-1398.

International Symposium on Requirements Engineering—RE '95 (C); March 27–29; University of York, Heslington York, England; Michael D. Harrison, Department of Computer Science, University of York, Heslington York, Y01 5DD, England; (44+904) 432732; fax, (44+904) 432767; e-mail, math@minster.york.ac.uk.

Fourth International Workshop on Responsive Computer Systems (CS); March 29–31; Hotel President, Berlin; Volker Tschammer, GMD-Fokus, Hardenbergplatz 2, D-10623 Berlin, Germany; (49+30) 254 99 226; fax, (49+30) 254 99 202; e-mail, tschammer@fokus.berlin.gmd.d400.de.

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Southeastcon '95 (Region 3, East NC); April 2–5; Sheraton Imperial Hotel and Convention Center, Research Triangle Park, N.C.; Charles J. Lord, 108 Huntington Circle, Cary, NC 27513; 919-781-8148.

Infocom '95 (C, COM); April 2–6; Park Plaza Hotel, Boston; Celia Desmond, Stentor, Floor 6B, 33 City Center Dr., Mississauga, ON, L5B 2N5, Canada; 416-615-6507; fax, 416-615-8421.

International Reliability Physics Symposium (ED); April 3–6; Riviera Hotel, Las Vegas, Nev.; Joseph W. McPherson, Texas Instruments Inc., Box 655012, M/S 385, 13353 Floyd Rd., Dallas, TX 75243; 214-995-2183; fax, 214-995-2932.

Second Topical Symposium on Combined Optical, Microwave, Earth and Atmosphere Sensing (GRS, LEO, MTT); April 3–6; Atlanta Renaissance Hotel, Atlanta, Ga.; Melissa Estrin, IEEE/LEOS, 445 Hoes Lane, Box 1331,

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Piscataway, NJ 0855; 908-562-3896; fax, 908-562-8434; e-mail, m.estrin@ieee.org.

14th Southern Biomedical Engineering Conference (EMB); April 8–9; Holiday Inn Downtown, Shreveport, La.; Debi P. Mukherjee, Department of Orthopaedic Surgery, Louisiana State University Medical Center, 1501 Kings Highway, Shreveport, LA 71130-3932; 318-675-6187; fax, 318-675-6186; e-mail, dumkhe@pop3.lsumc.edu.

28th Annual Simulation Symposium (C); April 9–13; Crescent Hotel, Phoenix, Ariz.; Enrique V. Kortright, Computer Science Department, Nichols State University, Thibodaux, LA 70310; 504-448-4406; fax, 504-448-4927; e-mail, ek@reality.nich.edu.

First Malaysia International Conference on Electromagnetic Compatibility—ICEMC '95 KUL (Malaysia Section); April 11–13; Shangri-La Hotel, Kuala Lumpur; Hussein Ahmad, Universiti Teknologi Malaysia, Fakulti Kejuruteraan Elektrik, Jalan Semarak, 54100 Kuala Lumpur, Malaysia; (60+3) 290 4219; fax, (60+3) 293 4844.

Fourth International Symposium on Database Systems for Advanced Applications (C); April 11–14; National University of Singapore, Lower Kent Ridge, Singapore; Chung-Kwong Yuen, Department of IS&CS, National University of Singapore, Lower Kent Ridge 0511, Singapore; (65) 772 2831; fax, (65) 779 4580; e-mail, yuenck@iscs.mus.sg.

Intermag '95 (MAG); April 18–21; Marriott Rivercenter Hotel, San Antonio, Texas; Diane Suiters, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, DC 20005; 202-639-5088; fax, 202-347-6109.

First International Conference on Algorithms and Architectures for Parallel Processing (Queensland, Singapore Section et al.); April 19–22; Mayfair Crest International Hotel, Brisbane, Australia; C. W. Chan, Department of Electrical and Computer Engineering, University of Queensland, Queensland-4072, Australia; (61+7) 365 3985; fax, (61+7) 365 4999.

International Workshop on Charge-Coupled Devices and Advanced Image Sensors (ED); April 20–22; Dana Point Resort, Dana Point, Calif.; Eric R. Fossum, Jet Propulsion Laboratory, M/A 300-315, 4800 Oak Grove Dr., Pasadena, CA 91109; 818-393-0045; fax, 818-354-3128.

Instrumentation and Measurement Technology Conference—IMTC '95 (IM, Boston Section); April 24–26; Westin Hotel, Waltham, Mass.; Robert Myers, Conference Coordinator, 3685 Motor Ave., Suite 240, Los Angeles, CA 90034; 310-287-1463; fax, 310-287-1851.

International Computer Performance and Dependability Symposium (C); April 24–26; University of Erlangen–Nurnberg, Germany; Wolfgang Hohl, Informatik III, University Erlangen–Nurnberg, Martensstrasse 3, D-91058 Erlangen, Germany; (91+31) 857 010; fax, (91+31) 393 88.

International Symposium on Circuits and Systems—Iscas '95 (CAS); April 28–May 6; Sheraton Seattle Hotel, Washington; Meeting Management, Iscas '95, 2603 Main St., Suite 690, Irvine, CA 92714; 800-321-6338; fax, 714-752-7444.

13th VLSI Test Symposium (C); April 30–May 3; Princeton Marriott Hotel, Princeton, N.J.; Prab Varma, CrossCheck Technology, 2833 Junction Ave., Suite 100,

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Washington watch

Congress kills bill for telecommunications reform

Health care reform was not the only casualty in Congress this September. The Senate also scuttled, or at least postponed, monumental deregulation in the telecommunications industry.

The Antitrust and Communications Reform Act of 1994, written by Congressman Edward J. Markey (D-Mass.), passed overwhelmingly this past summer in the House of Representatives. Markey called it the "most important economic bill of 1994." The White House advisor on the information infrastructure, Mike Nelson, said it was important for creating competition among local and long-distance phone carriers and the cable television industry. The goal was to drive down prices so as to jumpstart a variety of more capable and inexpensive services.

In somewhat different form, the bill also passed the Senate Commerce Committee, backed by Ernest Hollings (D-S.C.). Robert Dole (R-Kan.), however, issued a set of demands, many of them favoring the Baby Bell local telephone companies, that were perceived as being nonnegotiable and that led Hollings to drop the bill without bringing it to a floor vote. As a result, the popular House bill was scuttled, too.

Representative Markey blamed the Baby Bells. The legislation "is all gone because of their aversion to competition," he told *The Washington Post*. "They like to hold themselves out as entrepreneurial companies, but they're just telephone utilities."

U.S. competitiveness gets stronger

The latest assessment of critical technologies by the Council on Competitiveness, published in September, concludes that during the past five years the United States has "significantly strengthened its competitive position."

Out of 92 categories, ranging from electronic ceramics and display materials to robotics and broadband switching, the United States retained its commanding "strong" position in 30 categories and improved in 22, according to the 21-page report. In only two categories were there indications of decline: low-emission engines, and transmitters and receivers.

The United States was still rated "weak" in many categories, such as display materials and gallium arsenide. A similar report in 1991 had ranked these categories as "losing badly or lost." In addition, despite many jumps from "weak" to "competitive," not one technology category rating jumped from "competitive" to the highest rank of "strong."

"Strong" was defined as the position of world leadership considered secure for at least the next five years. Generally, software, biotechnology, computing, and visualization technologies ranked strong in this, as they had in the prior, report.

The report was based on 160 surveys of Government, academia, and industry that were conducted last spring. Formed in 1986, the council is a nonprofit, nonpartisan organization of chief executives from business, higher education, and labor. Its current chairman is Paul Allaire, chief executive officer of Xerox Corp.

Copies of the US $11.50 report may be obtained by calling the council in Washington, D.C., at 202-785-3990 or by sending a fax to 202-785-3998.

Imports again exceed exports

Although the future of electronics research and development may look brighter, U.S. imports of electronic products still exceed exports and the gap has grown since last year, according to the Electronic Industries Association, Washington, D.C.

During the first half of 1994, a record $48 billion electronic products were exported, up 16 percent from the same period in 1993. Imports of electronic products rose 18 percent to $55.3 billion. Included in the tally are computers, peripherals, solid-state devices, communications, electromedical equipment, electron tubes, passive components, and consumer electronics.

Virtual environments need actual aid

The potential for practical uses of virtual reality (VR) is so evident that the U.S. government should boost its R&D in the developing field, according to a September report by the National Research Council, Washington, D.C.

Excluding entertainment, four areas evidenced the most promise, according to the report: training, hazardous operations, medicine and healthcare, and design, manufacturing, and marketing.

Aware of the technology's potential, Japan has set up 10 national consortia for VR research, apparently surpassing all VR investment in the United States. This and other factors "could give Japan a major competitive advantage," the report warns.

The NRC committee, which is chaired by Nathaniel Durlach, a senior scientist at the Massachusetts Institute of Technology in Cambridge, urges the U.S. government to undertake a major coordinated research program in software and to facilitate network standards for VR. (Computer hardware, the report predicts, will probably continue to be advanced by commercial market forces.)

Among other suggestions for the Federal government: create an accessible national information repository for VR developments; support a small number of R&D teams, each focused on an application; and explore opportunities for early development of standards.

A highly readable 528 pages in its prepublication version, the report also offers a compilation of current research activities and industry applications. It even sketches some scenarios of how virtual reality might affect a hypothetical family five to 10 years hence.

"Virtual Reality: Scientific and Technological Challenges" is available for $69 from the National Academy Press in Washington, D.C., at 202-334-3313 or 800-624-6242.

National tech medals for IEEE members

Three IEEE Fellows were among the four individuals named in September by President Clinton to receive the 1994 National Medal of Technology.

Joel S. Engel and Richard B. Frenkiel, both Fellows, were each cited for fundamental contributions to the development of cellular mobile communications. Engel received the IEEE's Alexander Graham Bell award in 1987.

Another Fellow, Irwin M. Jacobs, was cited for his leadership in digital wireless communications over the last 25 years and for his development of code-division multiple access, a commercial technology adopted as a U.S. digital cellular standard.

Also cited was H. Joseph Gerber for development of manufacturing automation systems, especially in the apparel industry.

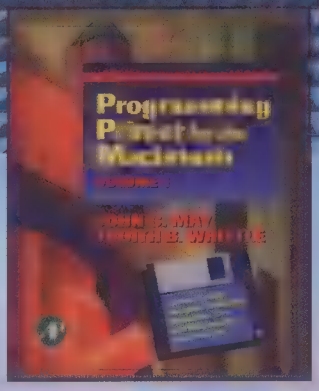
Two companies were honored: Amgen, Thousand Oaks, Calif., for innovative therapeutics based on cellular and molecular biology; and Corning Inc., Corning, N.Y., for "life changing and life enhancing inventions which made possible entire new industries—lighting, television, and optical communications."

John A. Adam — *Washington Editor*

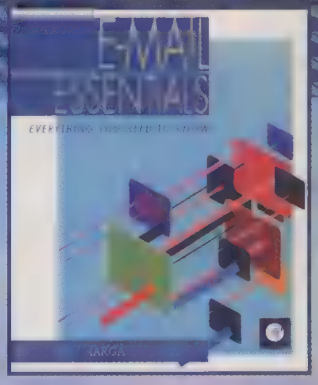
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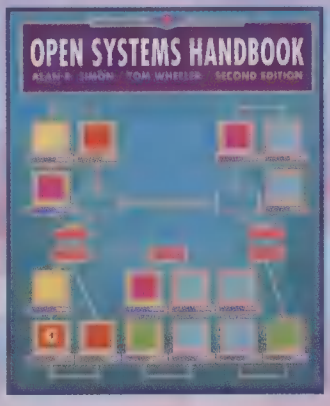
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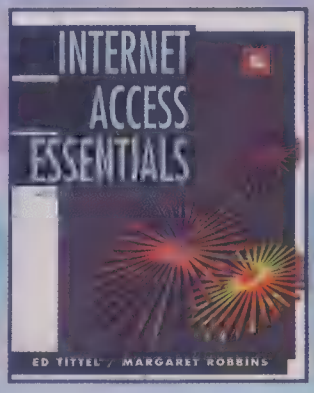












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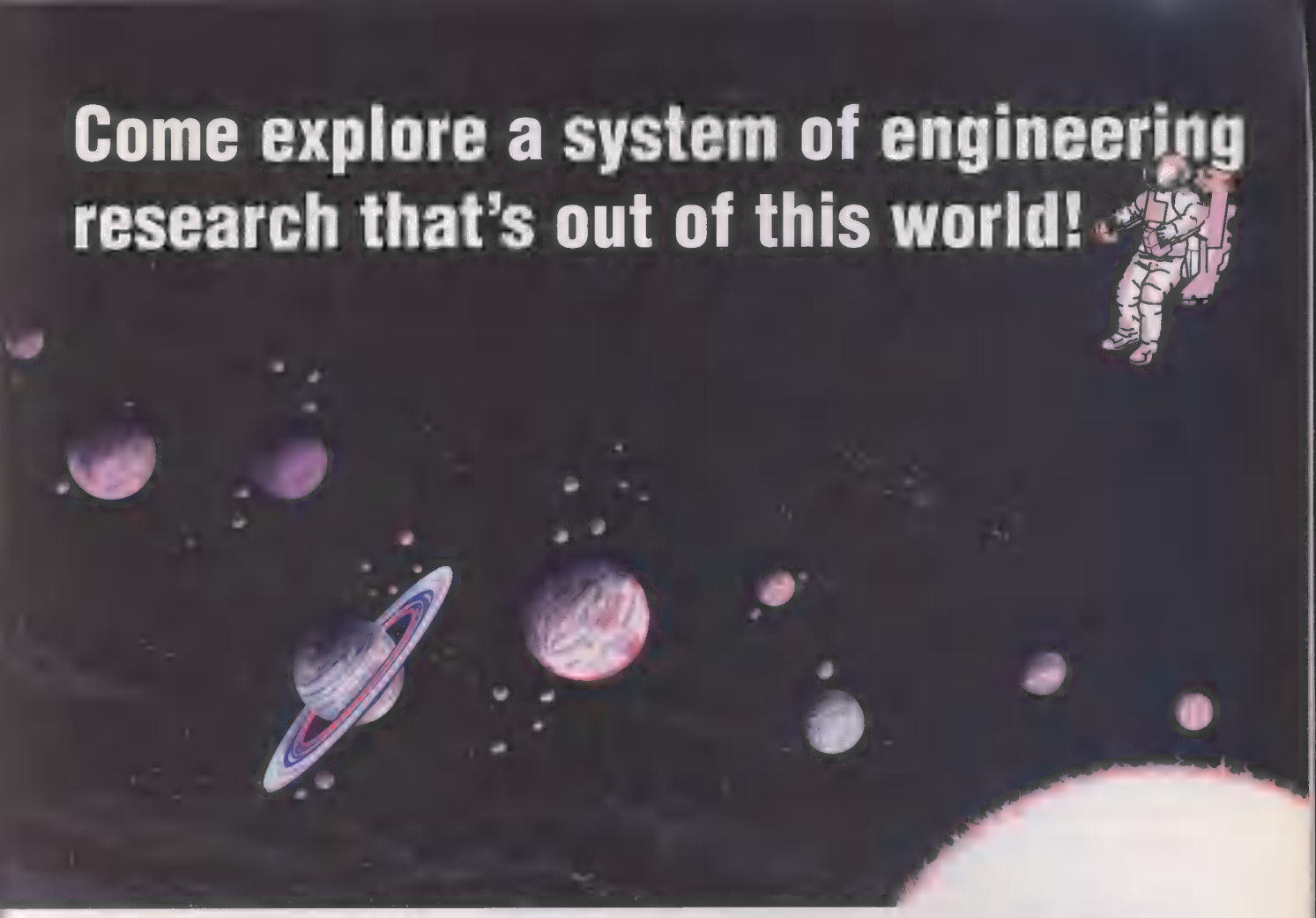
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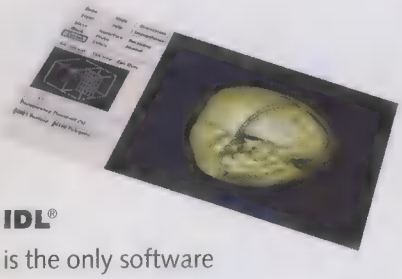
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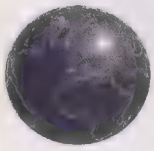
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Reflections

Who should get the credit?

When I read in some magazine or newspaper about some whizbang new product, I often wonder where it came from—I mean, where it *really* came from. After years working within the engineering system, I still don't understand where things come from, or who deserves the credit for them. Periodically this mystery bothers me, when, for instance, I am asked to consider nominees for some engineering award.

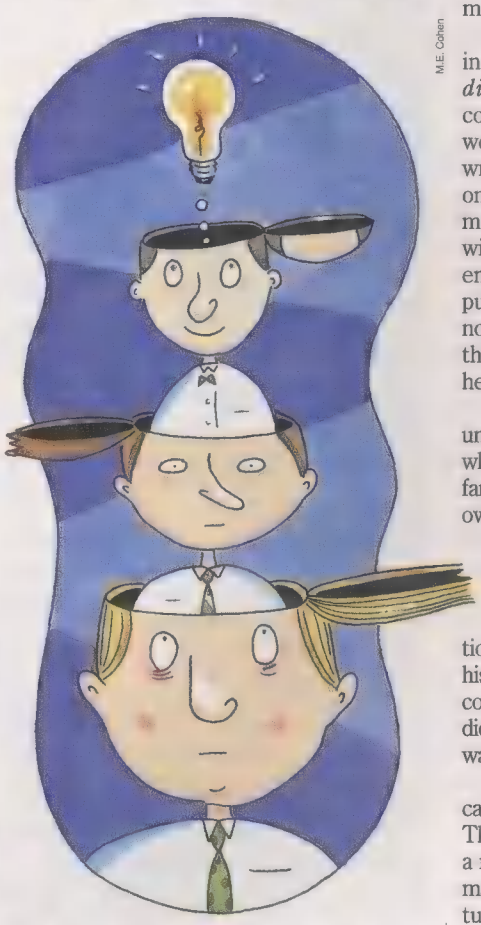
The model of the engineering world that I learned in school was a simple one. An engineer is working at his desk when suddenly a bolt of pure inspiration strikes. "Eureka!" he cries, grabbing a pen to begin writing a seminal paper in the new field. The patent is granted by return mail, and a special issue of the *Proceedings of the IEEE* has his picture on the cover. Companies race to produce the widget described in his paper, and within months he is being interviewed on "Lifestyles of the Rich and Famous." He lives happily ever after.

Somehow things don't work that way in what is blithely called real life. In case you haven't noticed, everything is actually quite murky, from the "Eureka" right through the "happily ever after." Nevertheless, even though we know better, we seek simple scenarios, we crave individual heroes, and we believe that the rewards should go to the creator of the intellectual idea. To say that some great invention coalesced out of primordial soup through a random instantiation of chaos theory is unappealing. I wouldn't say that myself in public, but sometimes late at night I wonder. This primordial soup is really pretty powerful stuff.

There is a new house being built next door to mine. When I go home at night, I can see the progress that has been made during the day. I wish that progress was as visible in our profession, but as I review my own work, I am unable to visualize any edifice that has resulted from my daily efforts. Instead, I have the sense of having contributed to that primordial soup that surrounds engineering, out of which will condense great ideas for which I will feel little personal responsibility.

For example, the other day I was reading a government report, and I happened upon some familiar phraseology. This was not a great new concept, but simply a nice way of looking at and thinking about a particular technology. I recently had read a similar exposition in one or two other places. The reason for mentioning this is that secretly I believe I originated this description myself, in some talks that I gave and some committees that I worked with. Somehow it got assimilated into the current culture and became part of what is now considered "conventional wisdom."

As tenuous as this connection between me and the sweep of progress may already be, it weakens on closer examination. You see, I'm



M.E. Cohen

not really sure that I started this particular thought process. Maybe I heard the idea somewhere else, and only passed it on. And after all, we are not talking about a great new idea, but only a way of describing something. Yet it is all a part of the process of socialization and consensus building that in the end could lead to world change.

There are a lot of us engineers out there, stirring the soup and making it bubble. Then when something definite and significant coalesces from the soup, we later seek to ascribe credit, because that is the way we are. But deciding who should get the credit for something is an interesting question that we seldom probe deeply. After all, no one wants to credit the soup. "Who published the first paper?," we ask.

Award committees work to find the author of the first paper, who is canonized as the "father" of whatever it is. Other award committees take note, and the author begins to travel up the chain of awards, as his connection with the achievement is legitimized. The soup is forgotten.

The problem is, I know of a number of instances where the people who actually *did* whatever it was—built the widget, commercialized the process, and so on—were totally unaware of the obscure paper written by the person who later was canonized. "See here," we say, pointing at the mathematics in the faded journal. "Your widget is implicit in these equations." The entrepreneur only raises his eyebrows in puzzlement. At stake here is whether or not Leonardo da Vinci should get credit for the invention of the submarine. After all, he published first (if posthumously).

Who gets the credit is one of the issues of undying interest to engineers; the other is who gets the wealth. In this regard, one quite famous engineer was relating the story of his own success, saying that he sometimes is host to young engineering graduates at his mansion in southern California. As he sees them staring at the opulence, he realizes that they are making the connection between his well-known invention and his obvious wealth. He feels it necessary to correct them. "My invention of [the widget] didn't get me this house," he tells them. "It was all the sales calls that I made."

Somehow I don't think that the "sales calls" bit is what the graduates want to hear. They want to cling to the belief that there is a rightness about the universe that will automatically reward the creator of the intellectual idea behind a technological advance. Alas, it is not so—nor is it clear on reflection that this is the way the world should work. In many cases the reward, and perhaps even the credit, instead should go to the people who championed the idea, took the risk, and put in the sweat to make it happen. This is an unpleasant thought. Like crediting the soup with the original invention, it doesn't fit with our engineering model of the world.

So in some abstract sense, when I read about a new widget, I feel partly responsible. Like you, I am a part of the soup from which it came. All the same, it would be nice to have the credit, and nicer still to have the reward!

Robert W. Lucky

Engineering layoffs: facts and myths

Being 'technically vital,' proficient in a hot specialty, or retrained does not guarantee a job in today's market

Last year engineering unemployment in the United States rose to a 50-year high, topping 4 percent—a level that has held through the first half of this year. This rise has continued despite the fact that the unemployment rate of experienced civilians at large has fallen since 1992 and that of experienced professionals seems to be leveling off.

Moreover, while many indications suggest that an economic recovery is under way, the fact is that layoffs in high-technology companies are continuing. According to the annual survey of the Aerospace Industries Association (AIA), Washington, D.C., fully a third of aerospace jobs have been lost since 1989—13 percent of them in 1993 alone—and another 5 percent are expected to be gone by year end.

The aerospace industry is not alone. In February, AT&T Corp. announced that it planned to cut perhaps 15 000 jobs by 1996, while Nynex Corp., New York City, said it would cut another 16 800 jobs over the next two years, half of them in management.

Not only are permanent jobs scarce, but a lot of vacant ones pay 10–50 percent less than such positions paid only a few years ago, and may also demand relocation. In other words, the chances of a laid-off engineer landing an equivalent job with a similar company in the same locale at comparable compensation seem to be small.

In spite of all the talk about job possibilities through conversion and dual use, engineers are finding that the skills they honed in the defense industry are simply not needed in the commercial world. Even worse, survival skills that were sufficient for landing a job in the past—such as keeping technically current and networking with one's peers—are not effective today. More and more engineers are finding that technical expertise is not enough to get or keep a job; increasingly, a premium is being placed on certain *nontechnical* skills as well. Moreover, according to at least one observer, the full-time job itself may be disappearing as a way of structuring work.

This article is the third in *IEEE Spectrum*'s ongoing examination of engineering unemployment [see "'90s employment: some bad news, but some good," *Spectrum*, December 1990, pp. 32–43, and "Jobs at risk," *Spectrum*, August 1993, pp. 18–35]. In contrast to the first two, which were written with the help of international correspondents and focused on global trends, this report restricts itself to the experiences of some engineers in the United States.

Whereas the other two were statistical analyses, this report seeks to give a human face to the numbers by recounting problems faced by laid-off engineers. Through their eyes, it also addresses such questions as: how successful has keeping technically vital been in making these individuals immune to layoffs? What hot new job areas have they found or not found? How well does the defense-to-commercial conversion appear to be working?

In this article the case studies are highly personal views. Official company representatives or other engineers in other fields or other parts of the country may have differing outlooks. Nonetheless, the experiences of these engineers suggest that, at least in certain contexts in today's work world, while some commonly believed assumptions may be facts, others are myths.

Myth: Being at the cutting edge of technology makes an engineer desirable.

"The vigilant engineer will have no problem identifying new areas to explore, provided he/she is receptive to the signals received," writes Ken Laker, the IEEE's Vice President–Educational Activities, in his column for the winter 1995 *IEEE Education Society Newsletter*. ". . .[T]he individual must maintain the fundamental skills essential for effective professional practice and should continue learning about changes in audience (customer) expectations and how the latest developments in the field can meet these expectations."

So far, so good. But there's another half to that equation that frequently goes unrecognized. Not only must an engineer keep current and be able to suggest how new developments can help a company to meet changing expectations—the company itself must have managers who welcome an innovative proposal and who have the guts to accept one that is sound. Otherwise, even the most talented, technically current, and professionally assertive engineer may still be out of a job.

SAVING NASA'S BACON. Take the case of Dennis Hancock, 46, former senior scientist at Lockheed Palo Alto Research Laboratories in Palo Alto, Calif. Six months after helping bring about the National Aeronautics and Space Administration's (NASA's) first successful servicing mission to correct the faulty optics of the Hubble Space Telescope, the company laid him off (along with 1000 other employees). Actually, that is not how it was described. "I'm still a Lockheed employee as of today," Hancock said in an Aug. 10 interview. "I'm just not getting paid." His annual salary had been US $78 000.

Hancock's 18-year career has been a series of firsts in *avant-garde* technologies. After receiving his BS and MS in 1970 and 1972 in applied physics with a specialty in lasers from Case Western Reserve University, in Cleveland, Ohio, he worked for IBM Corp., Endicott, N.Y., for five years and SRI International, Menlo Park, Calif., for another five years before joining Lockheed in 1984. At IBM, he helped develop optical character recognition equipment. At SRI, "I was one of the first people to measure the optics of oceans for laser communication with submarines from satellites," he recalled.

His last project at Lockheed was to use virtual reality to prototype engineering designs. Specifically, he single-handedly created three-dimensional visualization software called Preview (Prevent Real Errors by Virtual Investigation of Engineering Worlds) in order to check the design of the corrective optics intended for Hubble. Through Preview, Hancock found two crucial errors that would have jeopardized the mission had the corrective optics been built as orig-

Trudy E. Bell Senior Editor

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William McCormick/Huntsville Times

Mark A. Steinbuchel, 45, laid off in June from his position as a safety and environmental engineer for the Boeing Co. in Huntsville, Ala., attracted around 30 telephone calls and interviews when this photograph of him ran in the Aug. 10 issue of the Huntsville Times. *He wore the apron with its job-wanted ad while flipping hamburgers at a benefit barbecue.*

inally designed [see "Prototyping the Hubble fix," by Dennis Hancock, *Spectrum*, October 1993, pp. 34–39].

This application of computer graphics demonstrated how concurrent engineering, by integrating the work of four contractors, could be employed in developing a working model before the actual mechanisms were built. NASA used this predictive capability for the first time in testing the first Hubble servicing mission, which went off without a hitch last December.

Hancock's role in the triumph was trumpeted on the front page of the March 11 issue of Lockheed's company newspaper *Star*; he was asked to give presentations on his work to the U.S. Air Force; and at a June 7 fete sponsored by Lockheed at the Technical Museum of Innovation in San Jose, Calif., to highlight the company's role in the Hubble fix, the special draw was Preview. But his talk at the museum that night turned out to be his last project for Lockheed. When Hancock walked out of the museum that night, "I was out of work."

After the corrective optics' highly visible demonstration of the power of virtual reality to prototype engineering designs, Hancock attempted to elicit interest within Lockheed for Preview's applicability to other company projects. "I talked to all the people whose pictures were on the wall," he said, but his immediate manager was "not interested" and the division director "did not even return my phone calls."

The head of the research center did procure an invitation for Hancock to participate in a two-day engineering strategy session at the corporate offices in Los Angeles. But Lockheed would not pay for it because there was no contract to which his salary, airfare, rental car, and hotel bill could be charged. He recounted: "I was getting all this 'Great stuff, kid, wave of the future. Will you come down here to LA and spend $1500 of your own money to show us the wave of the future?' "

Hancock still tries to interest NASA. His initial client, the senior optical scientist on Hubble, had calculated that by using Preview NASA could save $4 million to $6 million on the second Hubble servicing mission set for next year. Hancock submitted a proposal to test the prototype designs using virtual reality—at an estimated cost of less than $200 000—instead of working with models of instruments in water tanks to simulate weightlessness. For the first servicing mission, the technology cost only $50 000.

In early August, higher NASA management on the Hubble project squashed the proposal, saying there was no money in the budget. "He actually said, 'We're really conservative engineers and scientists here and we don't change easily, so we're not going to do it,' " Hancock recalled.

Hancock believed the myth that doing a good job is all that is needed to have job security. "I'm a bit burned out about corporate platitudes: work hard, learn skills, work more efficiently. I thought I was *doing* all that," he reflected. "It's made me examine careers. There are plenty of people without advanced degrees who did the 'wrong' thing who've sold companies for $8 million. These are the people I now go to for financial loans. I did the 'right' thing and now I'm a famous dirtball."

Myth: Having many talents will set an engineer apart from the crowd.

"Engineers who are multifaceted are going to do well," stated Philip A. Lapp, past president of Canada's Association of Profes-

sional Engineers of Ontario, quoted in last year's report on engineering employment "Jobs at Risk" [*Spectrum*, August 1993]. Graduate degrees, additional degrees in business or nonengineering subjects, and fluency in several languages were cited as additional assets for engineers.

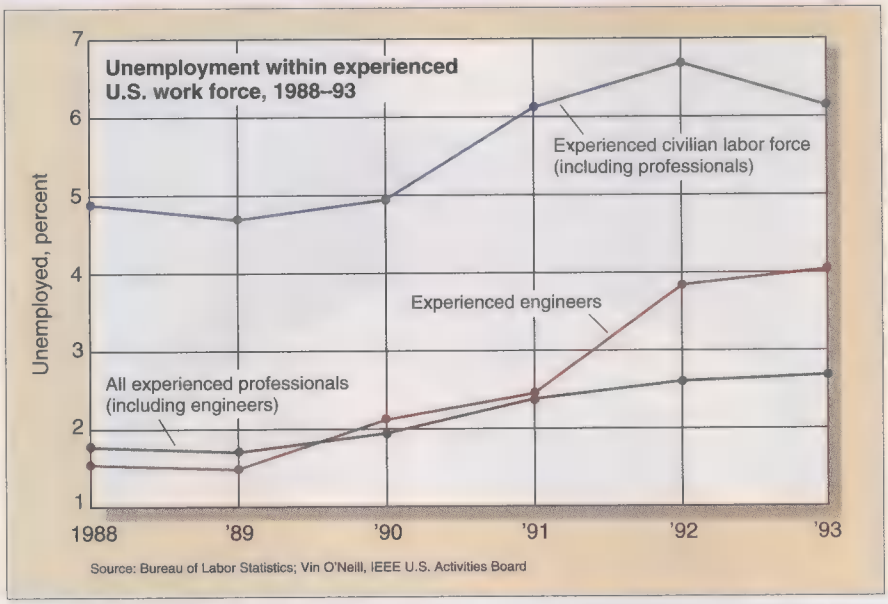
Well, even all those talents are not necessarily a shield against being laid off, as Larry Smith, 47, discovered after he was terminated on Aug. 12 from his $84 000 position as program development manager at Hughes Information Technology Co. in Reston, Va. (His name has been changed at his request; all other facts are unaltered.)

Smith—who is a former chair of the Los Angeles Chapter of the IEEE Computer Society—not only has a degree in electrical engineering (BSEE, California State University in Los Angeles, 1970), but also one in law (J.D., Glendale University College of Law, 1976). Although he has never practiced as a lawyer or taken the bar exam, "I do understand contracts law better than the average engineer," he said.

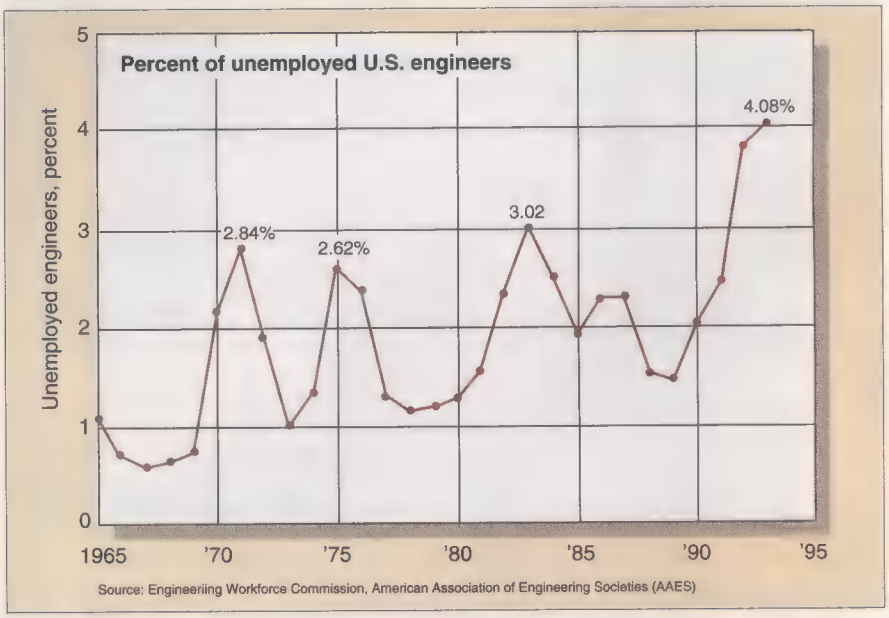
Smith is also familiar at first hand with the workings of the Federal government and politics. He served in Washington, D.C., as an IEEE Congressional Fellow and worked as a science and technology advisor to the California delegation and to Representative George Brown (D-Calif.) in setting policies for the restructuring of the defense industry. Because of his Eastern European heritage, Smith is fluent in Romanian and Hungarian, and has a working knowledge of German, Italian, Russian, and French.

At Hughes, his employer for 12 years, Smith specialized in managing large software-intensive programs. He also tried to introduce Hughes to business process engineering and to institute within the company ISO 9000, the new international quality standards and procedures that U.S. companies must meet in order to market their goods in Europe. Currently, NASA, the Department of Defense, and other Federal agencies are in various stages of implementing ISO 9000. Smith also is part of Technical Activities Group 176, the U.S. delegation through the American National Standards Institute (ANSI) to the International Standards Organization.

But Hughes, being a Federal contractor, was "very anxious to lower the price it was quoting to the Federal customer," and decided to cut the expenditures of Smith's small business unit in half by eliminating him and several others—the opening salvo in a wave of 4000 layoffs through the end of this year. "I never did get a satisfactory explanation of why me," Smith said, noting that the last bid on which he exclusively worked costed out at 10 percent below the lowest competitor's price. "They were pretty secretive. The only thing they told me was that they had too many program managers and didn't need one more."



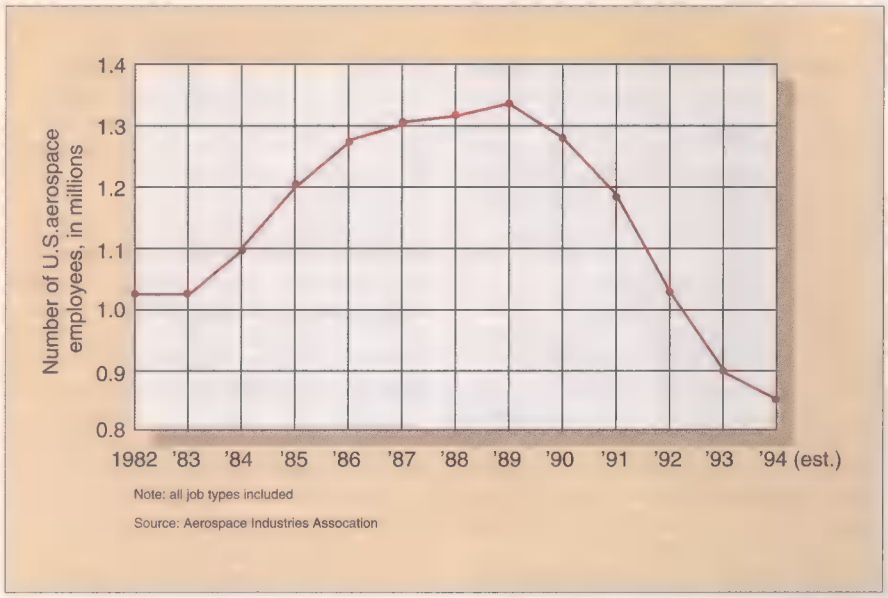
Whereas the unemployment rate of the experienced civilian labor force in the United States decreased in 1993, the rate for all experienced professionals has been rising slightly, while for engineers it has jumped. Now around 4 percent, it is the highest since World War II. The trend contradicts what has held true for past decades, when engineering unemployment was only a third that of general unemployment, usually rising and falling in synch.



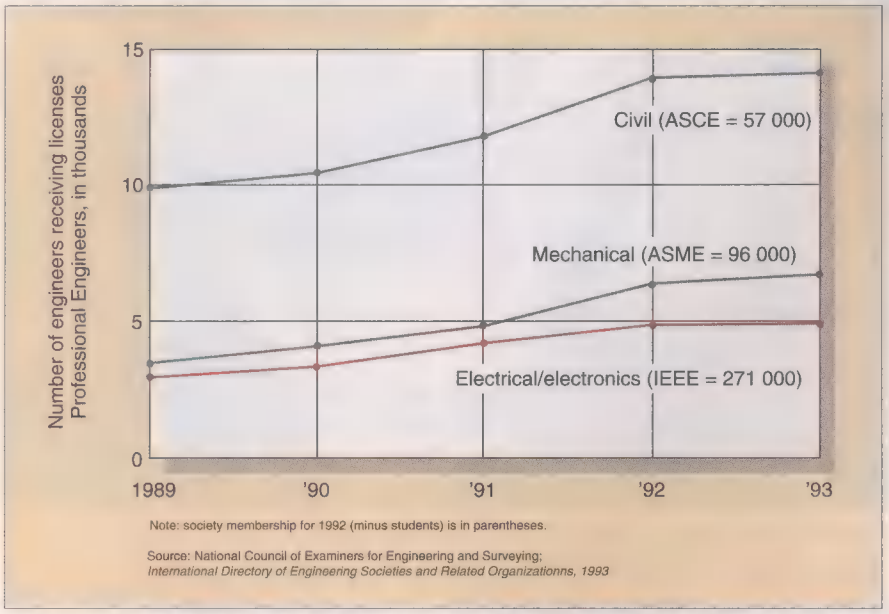
The unemployment rate of U.S. engineers is higher now than it has ever been. The situation is worse even than the "aerospace recession" of the early 1970s and the severe general recession of the early 1980s. Moreover, the total engineering labor force shrank from a peak of 1.89 million in the third quarter of 1990 to 1.68 million in the third quarter of 1993. An estimated 72 000 U.S. engineers are now out of work, compared with 49 000 in the previous high of 3 percent unemployment in 1983.

First, Smith asked to take his six weeks accumulated vacation to look for another job within the company; his request was refused, on the grounds that his existence on the payroll would affect the overhead rate. He was denied, too, the opportunity to apply for lower-level jobs in which he already had experience. But he did persuade the company to let him try out for a job in a wholly unfamiliar area—marketing satellite communications services. After four weeks, however, "it didn't work out, and so that was that."

Smith's technical background has some similarity to Hancock's: he helped to design simulators long before the technology was called virtual reality. Among them were the mission trainer for the F-14 fighter aircraft, the pilot simulator for the F/A-18 fighter/attack aircraft, and a simulator for missile defense in the Strategic Defense Ini-



The number of jobs in the U.S. aerospace industry at the end of 1993 is estimated to have been 909 000—the first time since 1978 that the number of aerospace jobs fell below 1 million. The industry's total work force has declined 32 percent from its peak of 1.33 million in 1989, and is expected to fall further to about 860 000 by the end of this year. Engineers and scientists fill about a quarter of these jobs.



The number of Professional Engineer (P.E.) licenses awarded to U.S. electrical engineers (EEs) rose by two-thirds between 1989 and 1993: it went from 2967 to 4926. But EEs still account for only 17 percent of licenses awarded: 23 percent go to mechanical engineers; and all of 49 percent to civil engineers. Also, assuming the profession's size to be reflected in the nonstudent membership of the professional societies, under 1 in 50 EEs have P.E. licenses, while 3 in 10 civil engineers do. By law in all 50 states, engineers consulting to the public must have P.E. licenses—a concern for laid-off members of the profession contemplating becoming independent contractors.

tiative (SDI). This last "ended up with a bunch of laurels, including getting Hughes [as a Lockheed subcontractor] the Lockheed Contractor of the Year Award," Smith noted.

But within Hughes, his polyglot and legal skills, plus his Government experience and his work in the hot fields of business process reengineering and ISO 9000, were "not an asset," Smith said—or at least not enough of one to let him keep his job.

***Myth*: Skills learned in defense work can be easily converted to civilian use.**

"We are seeing the first significant drop in the size of the modern 'military-industrial complex' since Dwight Eisenhower first coined this term in 1961," wrote Richard A. Ellis in *At the Crossroads: Crisis and Opportunity for American Engineers in the 1990's*, a special report published in January by the Engineering Workforce Commission of the American Association of Engineering Societies, Washington, D.C. "Americans are beginning to sense that the shift away from a defense-intensive economy which is so difficult for the former Soviet states may also be painful here."

"I don't think people are grasping how long it will take before [the job market] begins to pick up again—or what it will take to pick it up again," remarked Linda Lou Keen, administrator of Huntsville Area Technical Societies in Huntsville, Ala. The home of the U.S. Army's Redstone Arsenal, NASA's George C. Marshall Space Flight Center, and hundreds of high-tech companies, Huntsville has been hit by the double whammy of cutbacks in both defense and NASA's space station project. Estimates of the number of out-of-work Huntsville engineers range from 3000 to 6000—plus several times that number more in administration and support personnel. In 1993 alone, the 250 high-tech companies operating within the Cummings Research Park on the western edge of the city lost over 3500 out of 22 000 jobs.

FRYING PAN TO FIRE. Jack Liverman, 44, was a communications engineer at Teledyne Brown Engineering, ■ Huntsville contractor providing systems engineering and technical assistance for the U.S. Army Strategic Defense Command. Liverman was the assistant program manager for communications, analyzing and defining the technical communications requirements of the battle management, command, control, and communications systems needed for the missiles that were to defend the United States as part of the National Missile Defense system.

In October 1993, the Federal government cut the program's funding, converting it from a production to a research effort. Liverman was laid off from his $59 000-a-year job in late January 1994.

His whole career had been wrapped up in defense programs. After receiving a BSEE from North Carolina State University in 1973, he served seven and a half years in the U.S. Air Force as a communications officer, evaluating operational communications systems.

Liverman then worked for nine years at Mitre Corp.'s Federally funded research and development center in Colorado Springs, Colo., as a member of the technical staff, eventually earning a salary of $51 000. There he performed systems engineering and interoperability analyses for the United States Space Command, the North American Aerospace Defense Command, and the Air Force Space Command.

In late 1990 and early 1991, Mitre began laying off and offering early retirement to approximately 12 percent of its engineers in Colorado Springs, and was talking of

more layoffs for 1992. The writing was on the wall, and Liverman started looking for another position outside Colorado, landing the job and a $6000 raise at Teledyne Brown in Huntsville in October 1992.

"It looked good" at Teledyne Brown, Liverman recalled. "They had a five-year contract with the USA Space and Strategic Defense Command." But a month after he arrived, "they started talking layoffs." Within 15 months, Liverman was on the street with other Teledyne Brown engineers.

DEFENSE SKILLS NOT NEEDED. Since a job in defense work seemed out of the question, Liverman applied to local commercial communications outfits, such as AdTran Inc. in Huntsville, which designs communications switching systems. But he was shocked to find his defense background had taught him skills of seemingly no use commercial work.

"The big difference between defense engineering and nondefense engineering is that there is more design work in commercial work," Liverman explained. "In defense work, you hold off on getting your design engineers strongly involved until you get the government locked in on the requirements—otherwise you get what's called 'requirements creep' and are always in a redesign mode."

Liverman's forte in U.S. Air Force and Government work was systems engineering: analyzing what was needed for a large integrated system, defining the requirements and specifications, and then testing the systems after installation to ensure their fulfillment of the original requirements. "The Air Force didn't want their communications officers doing design work," Liverman recollected. "They hired contractors to do their design engineering, and so I wasn't able to develop a design background."

In a commercial project, however, requirements definition and specification is a much shorter process, Liverman explained. There is a greater need for designers up front because the company is moving fast to stay ahead of the competition. "And without the design background, I can't get a foot in the door," he said.

Even his oversight background appears irrelevant in today's commercial world. "I've taken courses in organizational behavior and R&D management to try to enhance my six years of management experience to get into a better position for commercial work. But many companies are downsizing their management force, and engineers with 16 to 20 years experience are being cut out." The only positions that seem to be expanding are those for new college graduates or junior engineers, who are paid less.

Liverman has sent his résumé to companies in Georgia, Indiana, Mississippi, North Carolina, Tennessee, and Virginia, and has contacted his previous employers in Colorado and Massachusetts. But here he's encountered a third problem: with so many talented engineers on the street, companies can afford to be very specific about the qualifications of new hires.

"A company in Georgia is looking for GPS [Global Positioning System] engineers," he explained. "I once taught the GPS concepts to communications officers while on active duty. But since I don't have previous design or development experience with GPS systems, they're not interested. Companies now want only to hire people with so many years with a specific programming language or a specific suite of hardware, who will work for less money, and who will relocate."



Marc Bondarenko/Gamma Liaison

Communications engineer Jack Liverman, 44, was laid off in January from Teledyne Brown Engineering. But his skills in analyzing and defining communications requirements for battle management are not in commercial demand. So he has perforce started a new career—as a sales associate for Radio Shack at the minimum wage of $4.25 per hour.

In July, Liverman spent five weeks as a technician for $6 an hour installing wiring, speakers, and microphone jacks for sound systems in courthouses in Lake Charles, La., and Urbana, Ill. "I did the nonengineering work; they already had an engineer to do the design and test work," the communications engineer said.

Aside from that one job, Liverman survived on his wife's store manager income and his unemployment insurance ($165 per week—one of the lowest in the nation) until the beginning of August. He is now working as a sales associate for Radio Shack at minimum wage—$4.25 per hour. He is trying to get into the manager trainee program, which would pay a minimum of $7 per hour. His first paycheck in September netted him $255 for two weeks' labor—$75 less than he would have received on unemployment.

"They say that in the long run there're going to be new jobs," he observed, "but how long is the long run?"

***Myth:* Continuing education or reeducation will keep an engineer employable.**

"One of the stories you hear is engineers flipping burgers. The guys flipping burgers for the most part should be. They've not maintained their technical marketability," declared Pete Lewis, IEEE staff director of educational activities in Piscataway, N.J. "Engineers have to be aggressive about protecting their careers. Next to their house, the most expensive investment they—or their parents—have made is their career." In Lewis's view, engineers should consider committing proportionately as much time and money to maintaining and enhancing their career as they spend on maintaining and improving their house.

Lewis continued: "I'm appalled to find how many engineers are not active members of their professional societies. It may be a condition of their prior womb-to-tomb employment structure where the company took care of them. Many companies provide job-specific training, but individuals have to look beyond the corporation to broaden their perspective."

He cited the aerospace industry as an example. "A lot of aerospace engineers have the knowledge and skills to go into bioelectronics or environmental mitigation.

But they have not made themselves aware of the alternative science."

Linda Lou Keen, of Huntsville Area Technical Societies, disagreed: "The ones flipping burgers are the ones still young enough to do it, or who have small children to support." On the other hand, she concurred with Lewis on alternative careers. "A little bit of reeducation would get a lot of them into another field. I don't know what that field might be—alternative fuels, solar energy, reduction in garbage, environmental engineering. . . ." Keen noted, however, that practically speaking, a person who has been out of work for nine or 10 months cannot even afford the tuition for night classes.

ONE THOUSAND HOURS OF CLASSES. Just what is the demand in environmental engineering? How successful are reeducated engineers at finding jobs once they have trained for a new field that allegedly has more promise—and just how good are those jobs?

Anent the first question, consider the case of Mark Steinbuchel, 45—no retread aerospace engineer, but a safety and environmental engineer with 22 years of experience. Until June 2, he was manager of safety, health, and environmental affairs for the Boeing Defense and Space Group in Huntsville, earning $52 100 a year.

Moreover, he has flipped hamburgers to good effect. At a picnic for Drug Awareness Day in Huntsville on Aug. 9, Steinbuchel worked the barbecue grills while wearing a white canvas apron on which he had penned in large black letters the following advertisement: "UNEMPLOYED AEROSPACE WORKER. PLEASE ASK ME FOR MY RESUME AND GIVE ME THE MEANS TO AGAIN SUPPORT MY WIFE AND THREE CHILDREN SO I WON'T HAVE TO WEAR THIS RIDICULOUS APRON IN PUBLIC ANYMORE!"

He drew so much attention that a 14-by-20-cm color photo of him appeared on the front page of the Local/State section of the next day's *Huntsville Times*. "An ad that size would have cost about $500," he noted. "It was an extreme thing, but I'm not afraid of being embarrassed. I've received over 30 phone calls and lunches."

Before joining Boeing in 1980, Steinbuchel worked for several insurance companies as a loss-control engineer. He received an A.A. in fire protection at Wichita State University in Kansas and a BS in industrial technology from the State University of New York at Albany in 1978. He has also invested 22 graduate hours at other schools toward an MBA.

Long before the phrase was invented, Steinbuchel was looking after his technical vitality. In 1977, he became professionally certified as both a hazard control manager and an emergency medical technician; both require that a certain number of classes be completed every year to maintain the certification. In addition, during his 14-year career at Boeing, he completed more than 1000 hours of training in specific skills as well as graduate-level courses in management, business, and governmental regulations.

He was given three months' notice at Boeing before he was caught in the company's fourth round of layoffs, which concentrated on a whole tier of first-line managers. "I tried to transfer within Boeing," he said, "but the 777 [transport] was cash-poor on the commercial side. And my pinhead of a supervisor would not let me drop back to a nonmanagement position."

Since June, Steinbuchel has managed to rustle up some local consulting work in environmental engineering. Like Liverman, he's been aggressive about sending out his résumé and getting interviews out of state: Florida, Kansas, and Louisiana. He's also applied for Federal jobs with the Environmental Protection Agency and the Department of Labor's Occupational Safety and Health Administration.

A member of the American Society of Safety Engineers, he is the past president of two of its local chapters. "Networking within the professional society is your best resource," he declared. "You can't have too many friends." He also has worked with the local Catholic and Methodist churches, which sponsor job-help programs.

Thus, though environmental engineering is supposed to be the coming thing, unemployment has "hit across all professions," Steinbuchel noted. He went on: "Here in the newspapers, you don't see ads for garage sales or tag sales—you see ones for 'layoff sales.' Here's your chance to pick the bones of some poor engineer. You go to the house and find boats, Mac computers, satellite dishes, oscilloscopes, microwave antennas—all the kinds of toys that men seem to accumulate. But keeping them now is not as much of a priority as taking care of your family."

'THERE ARE NO HOT AREAS.' What is the success rate of retrained engineers finding jobs in a new field? And how good are those jobs? Before the massive layoffs in southern California, the University of California at Los Angeles (UCLA) Extension for continuing education offered a large selection of university-level courses on cutting-edge technology, primarily for engineers with degrees who were interested in enriching or furthering their professional goals. But since 1989, enrollment in aerospace-related engineering classes has diminished while that in information systems has blossomed, said Don Hausknecht, UCLA Extension's Manager of Information Sciences & Engineering Class Program.

Over the past two years, UCLA Extension, with the help of contract grants from local Private Industry Councils (PICs), has admitted two groups of out-of-work engineers into certificate programs in information systems. Both programs are designed to retrain them in new fields with, hopefully, more promising futures. One program of eight courses earns students a certificate in microcomputer and local-area network support; the other offers a certificate in minicomputer and microcomputer programming.

According to Hausknecht, the students include both men and women, most of them 40 to 50 years old and about half of them with bachelor's degrees in engineering. Typically they have worked in aerospace or manufacturing technology, but not with current computer technology.

What has been the success of graduates of the 1993 programs in finding jobs in their new fields? "We wished it could have been better," Hausknecht admitted. "Only about 50 percent found full-time employment at the end of three months." The second group, which has just completed the classes, has fared better: "Already almost half are placed in training-related jobs."

The extension has been more aggressive about marketing the skills of this year's classes. Mailings on university stationery with brief résumés and a cover letter are being sent to possible employers in the PICs' area as well as to placement firms.

Nonetheless, UCLA Extension will not seek further PIC contracts in engineering reeducation at the end of the present contract. The university does not have the expertise or resources to be in the job placement business, Hausknecht said, while "the contracts with the PICs require successful placement of the participants." He strongly advises any school wanting to start its own reeducation program "to establish a cooperative contractual arrangement with the funding agency and a professional job placement firm" first, before offering courses.

Asked what engineering areas had high demand for good people, Hausknecht replied: "Before 1989, you used to see headlines 'XYZ Corp. to Hire 2500 Engineers for New Defense Contract.' You don't see that any more. In that sense, there are no hot areas."

Fact: The salaries of full-time engineers are falling.

The statistics compiled by the Engineering Workforce Commission "testify to the weakened demand for engineers. For more than five years, the buying power of compensation scales for most engineers has been declining," Richard Ellis wrote in *At the Crossroads*. Certainly the varied experiences of the people interviewed for this report confirm that observation from many different perspectives.

At the end of 1993, while still at Teledyne Brown but facing a layoff, Jack Liverman actually turned down a job offered over the telephone by a Colorado Springs company. The salary was $10 000 less than he was then making at Teledyne Brown, with no relocation visit, no moving expenses (an estimated $8000), and no house-hunting trip. "At that time, the numbers didn't seem reasonable," Liverman said. "But right now I'd jump at it."

Similarly, despite 22 years of experience in the supposedly 'hot' field of environmental engineering, Mark Steinbuchel has dis-

covered that most jobs for which he has interviewed have a salary of $35 000. He said he'll feel lucky if he lands something even close to his old salary at Boeing $35 000.

About the UCLA Extension students with their year's reeducation and certificate, Hausknecht said: "If they are placed at the entry level, they're looking at salaries ranging from the high twenties to about "

Linda Lou Keen noted that of 23 people who were placed through the Huntsville Area Technical Societies' job search and assistance program between June and September, "*none* got the equivalent of their former positions and salaries. That's a trend." Moreover, fresh graduates are also not making as much as their counterparts in the past, she added. "I think those big pay days are over."

She noted that the 23 people whom her organization helped place went into computer programming. "Computer programmers are in demand," Keen said, "although the jobs don't pay very well—about half what an engineer makes."

HAPPY JUST TO HAVE A JOB. Gearldine Burwell, 32, a systems analyst for three years at Boeing Co. in Huntsville, was laid off in April as part of the company's general downsizing. Aggressive about furthering her career, she was just completing her last semester—funded in large part by Boeing's tuition reimbursement program—for an MS degree in computer and information sciences at Alabama A&M University. She received the degree in July.

Burwell was given three months' notice and even before her job ended began interviewing by phone for a new position with firms as far away as Kansas and Pennsylvania. "Systems analyst right now is one of the top things to be," she noted, "but right now is not the time to be looking for a job in Huntsville."

After mailing out 200 to 250 résumés, mostly in response to job advertisements in the local newspapers, she was granted perhaps 20 or 25 interviews. In September she finally received her first concrete job offer: senior data systems coordinator at Pemco Aeroplex Inc. in Birmingham, Ala.

The good news is that she landed a permanent job in half a year—despite the fact that the annual salary of $30 000 is $600 less than she was earning at Boeing and the round-trip commute is nearly 300 km each day.

"The time off made me really appreciate being employed," Burwell reflected. "One day you're making x amount, and the next day you're making nothing." At the Pemco job, she plans to take advantage of all in-house opportunities to learn as much as she can, "because if I have to go through this again, I want my résumé to be more marketable."

Fact: Some survival strategies may threaten a company's technical vitality. Demand is not only is weaker for individual engineers—it has also weakened for engineering services, unless they are available at very low cost. To compete in this environment, some engineering firms are revamping the way they do business in an effort to capture the low-margin work, which they figure is better than no work at all.

The problem with this approach is that, in a successful company, profit margins are used in part to increase the company's capital resources, including its intellectual capital. There are signs that relying on low-margin business to survive may, ironically, cost a company its lifeblood, that is, its technical currency and preparedness.



Marc Bondarenko/Gamma Liaison

Geraldine Burwell, 32, is in demand as a programmer. She is happy to have found another job within five months of being laid off by Boeing Co. Her new job at Pemco Aeroplex Inc. pays nearly the same salary as the one before—but requires a daily round-trip commute of nearly 300 km.

HIGH QUALITY VS. LOW COST. A company that has diversified its business in recent years, following the market into environmental and other areas, is Science Applications International Corp. (SAIC). Its headquarters are in San Diego, Calif., but it has more than 300 offices worldwide staffed by approximately 16 000 employees. Of the professional staff, 25 percent are degreed engineers and 44 percent are scientists.

SAIC started out in 1969 as a U.S. Government contractor and revenues from the Government still represent 90 percent of its total revenue. But over years of Federal cutbacks, its percentage of revenues from defense business has decreased from 68 percent five years ago to 50 percent today.

The best-known division of SAIC is the Research and Development Co. In 1985, SAIC formed a new division called SAIC Technology Services Co. in response to market pressures to minimize costs. The focus of the new division, according to Larry Trammell, its general manager, is to "provide the highest quality support services at the lowest realistic and achievable cost."

A lot of work "doesn't need the big guns" of high-tech R&D, Trammell explained. Many contracts need something simpler—keeping track of the configuration of radars and other equipment on individual aircraft, for example. Moreover, the Federal government, as well as some commercial companies, like to have a program handled cradle to grave by one team, all the way from R&D to installation to test and evaluation to operations and maintenance.

Not all those phases cost the same. R&D, with its reliance on specialized computers and prototyping software and hardware, is intrinsically more expensive than operations and maintenance. Whereas most large companies have a single large overhead that is allocated among various projects regardless of actual cost, SAIC, Trammell said, has "developed a system that is flexible enough to segregate and charge the *actual* cost of performance to each [part of a] program." If the high overhead of expensive computers for R&D is not needed for simpler engineering support contracts, he asked, "why burden them with it?"

Since SAIC's proprietary cost-accounting method allows costs to be accurately allocated, SAIC Technology Services can calculate the true estimated cost of a project and then enter the lowest possible bid, while assuring the parent company that it will not be taking a bath on unforeseen costs. And since the

Federal government—particularly under current budget pressures—prefers to accept the lowest bidder, that strategy can mean the difference between winning the bid and getting some revenue or losing the contract and getting none at all.

In 1993, SAIC Technology Services grossed $160 million in revenues, 10 percent those of SAIC as a whole, and that percentage of lower-rate business, Trammell said, is expected to increase.

SEEDS OF DESTRUCTION? Trammell admitted, however, that this is not all good news—and indeed may have high risks. He fears that the company's higher-rate business may cease to grow and may even decline. With the lower return to the company, "we cannot afford to do as much internal R&D or as much for our employees in the way of training programs. I contend that what we're seeing in the industry is somewhat of a mortgaging of our future."

Even stronger sentiments were expressed by 14-year SAIC veteran Joseph Fragola, division manager in SAIC's New York City office. "The future is to bid cheap, to sell Nordstrom quality at Kmart prices. But the reality is, it may be causing a general erosion of our technical infrastructure."

The people who work for Technology Services Co. typically must devote a higher percentage of their time to the contract. In contrast, those in SAIC R&D "can spend 15 to 20 percent of their time" on business development, research, preparing and delivering conference papers, working on white papers, and developing the technology useful for future bids, Fragola said. In other words, he contended, an employee working on low-rate business "is being used up. Technology moves on, and he can't keep pace. Eventually the low-rate business may become a repository of incompetence."

"So where does that leave a person who does not want to commit technical suicide?," Fragola asked. A company's strategy to capture low-rate business may create a moral dilemma for its engineers, who must keep up with the literature and plan for future jobs but also fill out their time cards. "Do you do research or write proposals for future work on the job, while charging the Government for the time?" he asked. "That's illegal. But what are the alternatives? Do you work on your own time and sacrifice your family? Or do you die, technologically?"

For fiscal year 1995, SAIC's low- and mid-rate business—although not all of it from Technology Services Co.—is projected to be 38 percent of the company's business, and may account for 65–75 percent by the year 2000, Fragola said. He added: "I refuse to join this rush to low-rate business, but it makes it harder for me to win [bids] because I have to compete within my own company at a higher rate."

Trammell pointed out one other long-range danger. "The cost of facilities is a fixed cost, but the more business you get at a lower rate, the less you're supporting those costs." In other words, by making each part of the company support its actual costs, the higher-overhead R&D work eventually becomes even more expensive to bid on, since the indirect cost associated with high-overhead work is no longer being allocated to the low-overhead work. The result may be a dwindling of the high-rate business. "We do worry about that," Trammell acknowledged. "We talk very often at management meetings about what business we're in, and what prices we're willing to accept for our services."

". . .[M]anagers can control the amount of work time and personal time available for TV [technical vitality], by the job demands that they place on their people," wrote Paul R. Gehrmann, director of systems software at IBM Corp.'s corporate headquarters in Somers, N.Y., in his March 8, 1993, study, *Technical Vitality of Technical Professionals: A Competitive Advantage of the 1990s*. "If every assignment is a crusade, where very aggressive schedule targets are most important and require extensive overtime, and the nature of the work does not result in vitality, vitality will suffer."

From surveys conducted in the course of preparing the study, Gehrmann found: "Guidelines or requirements. . . for the company time that a TP [technical professional] should spend on vitality activities range from 10% to 33%, with 20% the most frequently mentioned." He added: "Unimportant or unchallenging work is often a distinguishing characteristic of a non-vital organization."

***Fact:* The demand for temporary engineers is booming and compensation is high.**

"There is a tremendous glut of jobs out there and a shortage of engineers," declared Mark Fackler, president of Stellcom Technologies, a San Diego-based contract-engineering firm specializing in the placement of software specialists. "The temporary industry is growing and has been for years."

Keen agreed, observing that the programming positions coming to the attention of her Huntsville group are usually short-term jobs involving one- to two-year contracts. "That seems to be the future as well," she said. Moreover, because the Federal government works on a fiscal year from Oct. 1 to Sept. 30, and contracts are given out year to year, companies tend to hire and fire according to that pattern.

AN HOUR'S WORK, AN HOUR'S PAY. But how can Fackler assert, in the face of rising engineering unemployment and continued layoffs, that there is a glut of jobs and a shortage of engineers? The strongest proof, he said, is that customers today must agree to make an offer within a day or so, or else the engineer is likely to be unavailable. A year ago, the engineer might still have been available a month later.

When Fackler founded Stellcom Technologies in 1984 (then called State of the Art Computing Inc., a name it bore until this year), it was a one-person firm covering only southern California. Now it has 14 full-time administrative and support personnel and represents more than 100 software engineers; this year it opened an office in San Jose to service companies in northern California as well. The average job lasts nine to 10 months, Fackler said, so Stellcom has two to three engineers coming off a job every week. "People can work 2000 hours a year," he claimed, adding, "We don't guarantee that, of course."

Companies love it, Fackler reported. Temporary employees are especially attractive to firms in California, where state laws make it very difficult to fire people without cause. In his view, half full-time employees and half consultants "is a great mix—it allows the work force to fluctuate gracefully with the market."

The engineers love it, too. "You get to go to new companies, learn new technologies, see new management styles, work on different projects—it's very exciting," Fackler said. Plus, in contrast to the full-time positions that seem to offer salaries 30–50 percent below what an engineer made before being laid off, "We pay 30 to 50 percent more because of the risk." And unlike exempt employees in a corporation, the temporary engineers continue to earn their hourly wage while working overtime.

Stellcom Technologies also has a pre-tax 401(k) retirement plan (though the engineers' contributions are not matched by the company) and a pre-tax medical expenses plan. But there is no paid pension, health insurance, sick leave, or vacation: "You work an hour, you get paid an hour," Fackler said.

JOB SECURITY AN OXYMORON. ". . .[C]onsulting and engineering services companies. . . are now the largest single employment market for the profession," Richard Ellis observed in *At the Crossroads*. "The new age engineer is likely to be more independent, and is apt to be cynical about job security, a concept that looks more and more like an oxymoron."

One such cynic is Jane Doe, 40, for the last 3-1/2 years a software programmer for Stellcom Technologies who is now jobbing on a one-year contract for ABC Corp. (The names of the programmer and her client company, and identifying details of her personal life and specific work projects have been changed at her request; all facts pertinent to this article are unaltered.)

In the past, Doe said, employees who did a good job, were dedicated, and made an extra effort could expect to be rewarded in some way. "I don't see companies really valuing full-time employees now," she observed. "And with layoffs, you're no safer with a full-time job than as a contractor in terms of job security. I see no reason to become an employee."

Doe quit her last full-time job as a programmer at an insurance company to try contracting when layoffs seemed to be looming in early 1991. Her first contract with Stellcom Technologies carried with it

a 30 percent raise in pay. That contract, which had been slated to last only two months, ended up lasting 2-1/2 years, and she was much happier with the work. Now on her second contract as a programmer with ABC, Doe is earning a rate that translates into an annual salary of $80 000.

ABILITY FIRST, DEGREES SECOND. Doe's background also challenges traditional assumptions about what makes a technical person employable and successful. Her bachelor's and master's degrees from the late 1970s are not in engineering but in Asian studies. But she immediately went to night school for training in computers, and has been programming IBM-compatible PCs since 1981, learning primarily on the job.

And what about "technical vitality" and its role in staying competitive in a tough marketplace? Unlike most of this report's interviewees, who devote many hours to continuing education, training, or study on their own so as to keep ahead in their fields, Doe has no such inclination. "I'm comfortable with my skills," she said. "I don't have the ambition to be the best programmer there ever was. My focus is Japanese art and literature, and when I take a course, I lean toward those to give me balance. I just couldn't live, eat, breathe computers."

How can Stellcom Technologies hire a liberal arts major to program software and pay her at the rate of $80 000 a year? What counts more than formal education is the talent for conceptualizing large problems and coming up with solutions, Fackler said, and for that "some of our best engineers are philosophy and music majors."

It's a brand new world.

Fact: Some observers suggest the full-time job is disappearing.

". . .[W]hat is disappearing is not just a certain number of jobs, or jobs in certain industries, or jobs in some part of the country—or even jobs in America as a whole. What is disappearing is the very thing itself: the job." So wrote William Bridges in *JobShift: How to Prosper in a Workplace Without Jobs*, newly out from Addison-Wesley.

Bridges shows how the work week is actually an artificial unit, invented early in the 19th century for the factories of newly industrializing nations. "Before people had jobs, they worked just as hard but on shifting clusters of tasks, in a variety of locations, on a schedule set by the sun, the weather, and the needs of the day."

Now work is being revolutionized again—and again largely through technology. "The very conditions (mass production and the large organization) that created jobs two hundred years ago are disappearing." In Bridges' view, "Today's organization is rapidly being transformed from a structure built out of jobs into a field of 'work needing to be done.'"

Most of that work takes the form of individual projects, such as the development of a particular product. So it is becoming increasingly common for people to be hired only for the duration of the project, and released when the project is completed. "Jobs are no longer socially adaptive" to organizational needs, Bridges wrote, "and so they are going the way of the dinosaur." In what he calls the "post-job world," workers, including white-collar professionals such as engineers, will survive only if they operate as if they were self-employed—*even if they still happen to have a full-time position.*

BENEFITS AND RISKS. Bridges' is not a maverick viewpoint. Fackler, for one, has run Stellcom Technologies on that premise for years. "More companies are recognizing that contract workers are a necessity, a good necessity, and they need someone to get the work done," he said. He added that even full-time engineers must come to understand that "every day on a job, they're marketing themselves for the next job."

SAIC, too, has recognized that for years. Every employee works on contracts ranging from one to five years, so it is the responsibility of each, and of his or her management, to find another project when the contract ends, Trammell explained. In fact, SAIC facilitates the job search with an internal software system called Ajobb, which lets people look for advancement opportunities in other SAIC companies and offices. In addition, the company maintains a list of employees who are or may be available for other projects. Managers view this list first when looking to fill new positions.

Even some traditional employers have restructured themselves to become more like contract engineering houses, putting the responsibility for finding new jobs within the corporation on the employees themselves. But if projects are overly demanding, such a system can backfire. Instead of securing the labor of those with the motivation and talent to find a succession of contracts within the company—and weeding out the less assertive and able—it can grind down and force out the most dedicated.

Consider again the case of Lockheed Missiles & Space Co., the former employer of virtual-reality prototype designer Dennis Hancock. Federal government accounting practices dictate that a contractor, such as Lockheed, institute a system in which every employee has to bill every working hour to a particular contract, or else lose his or her job.

Within the company, this is blithely called having a charge number. "Unfortunately, the system does not provide a charge number to find a charge number," Hancock noted. So toward the end of a contract, "unofficially, workers will spend up to several weeks trying to find their next position within the company. Officially, most assignments emerge by immaculate conception," he said.

When Hancock was writing the software for virtual-prototyping Hubble's corrective optics, he knew that the NASA contract to which he was billing his hours would end in July 1993. He knew that unless he spent some time looking for his next contract, he risked not having a job. To meet NASA's testing schedule in enough time to allow for hardware changes, however, he was devoting 80–100 hours a week to Preview. Thus, Hancock recalled, he found himself in a dilemma: either spend all his time on the contract—essential if the software was to be completed and debugged by the deadline—or squeeze out some time to look within Lockheed for his next contract.

Hancock took the risk and devoted all his time to the virtual prototyping. He did so not only because he might not have been able to complete the job otherwise, but also because



Lockheed Missiles & Space Co.

Featured on the front page of the March 11 issue of Lockheed's company newspaper Star *was this photograph of Dennis Hancock, 46. The accompanying article described his use of virtual reality to prototype and test the design of the corrective optics needed for the Hubble Space Telescope. Three months later, Hancock was laid off.*

he thought the technology he was refining was so powerful that its applicability would be evident to others in Lockheed—and so would help him find his next internal contract when the one with NASA expired.

The result was that the right decision for NASA turned out to be the wrong decision for Dennis Hancock—and Lockheed, arguably, was the biggest loser of all.

Fact: Today, more than technical skills are needed to find work.

So answer those want ads. Network with peers, by all means. Send out résumés. Go on interviews. Keep up your technical vitality. But don't expect that those traditional techniques alone will guarantee you a full-time corporate job—even if you are at the top of your field.

And even if you have or land a traditional job, don't assume it will last until your retirement—because if Bridges' thesis is correct, there may be even fewer traditional engineering jobs in the next century.

But the world is not without hope. Here are some other things you may want to do to enhance your future marketability.

DO YOU NEED A P.E. LICENSE? If you are thinking about hanging out your shingle as a consultant, check whether your specialty requires you to obtain a state license as a professional engineer (P.E.). "If an engineer is offering his or her services to the public at large, and if the results of the services affect the safety of the public, the engineer *must* be licensed," said Roger B. Stricklin Jr., executive director of the National Council of Examiners for Engineering and Surveying in Clemson, S.C.

While a large number of civil and mechanical engineers are P.E.s, only a minuscule percentage of electrical engineers are licensed, Stricklin said, mainly because they tend to work for major corporations in fields that have industry exemptions. Companies seldom require a P.E. license from any employee who is not signing and sealing plans.

Gradually, though, the realization is dawning that growing numbers of civil and mechanical engineers are using computer-aided design and manufacturing programs to design structures. "You can kill as many people today with bad software as with a bad bridge design—something that most people don't think about, or choose to ignore," observed the IEEE's Pete Lewis, noting that the people who design the software should be as qualified as the people using it.

Moreover, with so many corporate downsizings and so many good engineers on the street, some EEs are realizing belatedly that "the job opportunities might be a lot better if they had 'P.E.' after their names," Stricklin added. Depending on an engineer's field and state laws, it may also make the difference between consulting legally or illegally.

Getting a P.E. license is usually easiest for engineers newly graduated from a program accredited by the Accreditation Board for Engineering and Technology (ABET), Stricklin noted, since the first step is an 8-hour exam on engineering fundamentals. After four years' experience on the job, applicants must take another 8-hour exam on the principles and practice of engineering.

'GO TO DALE CARNEGIE.' Enlarging technical competence is not sufficient. Also necessary is the ability to master new material quickly, get along with co-workers, be flexible, and express oneself verbally. To survive in a project-by-project world where one is always marketing oneself for the next job, engineers "all need to go to Dale Carnegie in addition to learning C++," said Stellcom Technologies' Fackler.

"Engineers are always accused that they can't talk and they can't write," added the IEEE's Pete Lewis. "They need to hone their public speaking and writing skills before their peers" in the nonthreatening environment of, say, meetings of their professional societies, to avoid exposing themselves to the severe criticism of a corporate vice president.

BECOME A VENDOR. Even an engineer with a full-time corporate job should think of himself or herself not as an employee with a boss, but as a self-employed company with a client—what Bridges calls "You & Co."

That means taking responsibility for all sorts of things the engineer may be used to leaving up to the company. "A lot of technical people out there are going to have to be more independent—have their own health insurance and all—so they can move from job to job," noted Keen. It also means having the self-discipline to save up for dry spells in between jobs—the key to Stellcom Technologies consultant Jane Doe's ability to enjoy her 10-week "summer vacation" between contracts.

KEEP ALERT. It is also important to recognize that the future may prove even less like the recent past than even a William Bridges predicts. For example, there was a time when an outside consultant was hired at great expense to lend seasoned expertise and the "big picture" perspective that a company lacked. This is the function that SAIC has fulfilled in analyzing the designs submitted for NASA's space station.

But could it be that the role of the consultant is also evolving? There are hints of this in Liverman's Government experience, when he, as a requirements specifications specialist, was told that a design background was not necessary: contractors were hired for that. Stellcom Technologies' Fackler noted that, though his temporary engineering talent is paid well, "we are *not* the ones who come up with the ideas for the projects."

Doe confirms that, in her experience, "contractors are more the 'worker bees.' Typically the company and its employees will do the design and hire contractors to do the coding. I don't get involved with design as much, and less so with requirements definition."

Could it be that the engineering world might end up with very small high-tech companies (compared to their present size) in which just a few employees do the high-level design work? Or might consultants split up into two types: designers and "worker bees"? What might that do to relative pay scales and the differential between employees and contractors?

There are more questions than answers, and comfort may seem small. Surviving in today's turbulent times is going to require separating fact from myth, and positioning oneself to have more skills than ever before. In this environment, which to so many people who have done everything "right" by the old rules has been so wrenching, just being in advanced technology and keeping technically vital may not be enough.

TO PROBE FURTHER. *JobShift: How to Prosper in a Workplace Without Jobs* by William Bridges (Addison-Wesley, New York, 1994) should be required reading to understand some of the reasons that joblessness is increasing in the United States, Europe, and Japan even though the global recession is over—and what individuals can do to adapt.

Richard A. Ellis zeroed in on the plight of engineers in *At the Crossroads: Crisis and Opportunity for American Engineers in the 1990's*, a special edition of the *Engineering Workforce Bulletin* (Nos. 130–131, January 1994); it sells for US $18 to IEEE members ($28 to nonmembers) from the Engineering Workforce Commission of the American Association of Engineering Societies, 1111 19th St., NW, Suite 608, Washington, DC 20036–3690, 202-296-2237.

Chapter 13 of *Career Advancement and Survival for Engineers* by John A. Hoschette (John Wiley & Sons, New York, 1994) addresses techniques for successfully surviving corporate takeovers, mergers, shutdowns, and workforce reductions.

Typical of recent articles on technical vitality, and their almost social-Darwinistic cast of thought, is "Survival of the fittest," by David B. Youst and Laurence Lipsett, *Spectrum*, October 1994, pp. 67–69. The article argues that occupational health resembles physical health: an engineer must keep working at it and looking ahead, not wait for obvious symptoms of trouble.

The IEEE has several publications helpful to laid-off engineers. One is the United States Activities Board's *Employment Guide for Engineers and Scientists* (3rd edition). The IEEE Educational Activities Board also has an Engineers Guide to Business monograph series for training in nontechnical job skills; among them are *Presentations that Work* by Carole MableKos, *Writing for Career Growth* by David McKown, and *Building Internal Team Partnerships* by Harry Roman.

Each IEEE publication is priced at $14.95 to members, $19.95 to nonmembers, and all are available from the IEEE Customer Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; from inside the United States, call 800-678-IEEE; from outside the United States, call 011-908-981-0060; fax, 011-908-981-9667.

Foreign R&D in the United States



Toyota Technical Center USA Inc.

At Toyota Technical Center USA Inc., situated in Ann Arbor, Mich., a technician tests the durability of an automobile seat. Toyota Motor Corp. is one of the many Japanese and other non-U.S. companies that have been adding to their U.S. research and development operations in the past several years.

A new study of European, Japanese, and South Korean R&D facilities in the United States reveals a marked rise in U.S.activity of this kind by foreign companies

Four years ago, Toyota Motor Corp. embarked on a major expansion of its R&D operations in the United States. It invested over US $85 million in two new technical centers in California and Michigan and spent a further $44 million to triple the size of Calty Research Design Inc., its design and research facility in Newport Beach, Calif. Then in 1993, the company opened a $110 million proving ground in Arizona.

Several automotive companies from Japan and Europe have since followed Toyota's lead. Nissan, Mazda, Mercedes Benz, and BMW, to name just a few, have either established new R&D operations or expanded existing R&D facilities in the United States.

These moves by leading non-U.S. automotive companies are part of a growing trend. Lately, the number of foreign companies conducting R&D in the United States has risen dramatically, and their existing U.S. facilities for that purpose have been significantly enlarged. The development is clearest in the electronics and biotechnology industries, as well as the automotive area.

How large is direct foreign investment in R&D in the United States? What exactly do these facilities research and develop? Why have non-U.S. companies set up new operations or expanded existing facilities for R&D in the United States? How do these firms decide where to locate? To address these and related questions, the operations of over 50 Japanese, European,

Manuel G. Serapio Jr. University of Colorado at Denver

Donald H. Dalton U.S.Department of Commerce

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Kobe Steel USA Inc., Applied Electronics Center

Researchers at Kobe Steel USA Inc.'s Applied Electronics Center in Palo Alto, Calif., are working to measure electrical and magnetic properties of sputtered rigid-disk media.

and South Korean R&D facilities were studied. All belong to the three industries mentioned above, which have the largest concentration of foreign R&D facilities on American soil.

Between 1981 and 1992, spending on U.S. R&D by businesses from elsewhere went from 8.8 percent of total company funding for R&D to nearly twice that figure—17.1 percent [Fig. 1]. (These are the latest figures available.) In hard currency, foreign-owned companies in 1992 spent $13.5 billion on R&D in the United States, including the R&D spending on their U.S. manufacturing, sales, and R&D subsidiaries. In 1985, the figure stood at $4.9 billion. (Incidentally, during the same five years, U.S. companies increased their own overseas R&D activities, though to a lesser degree, as the box on p. 30 shows.)

Concrete evidence for these outlays is the surge in the number of foreign-owned R&D laboratories to be found in California, New York, and many other states. There were fewer than 100 in 1985, but by the end of 1992, the number had jumped to over 250 owned by more than 100 parent companies from outside the United States. For 1994, preliminary figures from the U.S. Department of Commerce suggest the number of R&D facilities is now 300.

Japanese parent companies own about 150 of the 250 facilities, thus accounting for around 60 percent of all such operations [Fig. 2]. European and South Korean companies own 95 and 15 facilities, respectively. The greater Japanese presence might partly be due to the larger number of Japanese parent companies—62, as against 42 for Europe and 9 for South Korea. Moreover, the Japanese parents tend to have more facilities per company than their European counterparts do. For example, Matsushita, Sony, and Fujitsu combined have over 30 R&D laboratories in the United States.

As already noted, the industries in the hottest pursuit of U.S. R&D are electronics, biotechnology, and automobiles. In the electronics area, including computer hardware and software, upwards of 30 Japanese companies own more than 100 R&D locations in the United States. The seven Japanese automotive companies (Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, and Toyota) have established a further two dozen or so. Biotechnology, in contrast, is the focus of 60 percent of the European R&D facilities in the United States, with the lion's share owned by British, German, French, and Swiss companies. South Korean R&D facilities are concentrated in the electronics and automotive industries and belong principally to the country's largest conglomerates, such as Samsung, Daewoo, and Hyundai [see table, p. 28].

ACTIVITIES VARY. The foreign facilities differ widely from each other not just in the focus but also in the scope of their R&D operations. Some of them work on a wide array of technologies at a single site. One such is Philips Laboratories in Briarcliff, N.Y., which conducts R&D on computer hardware, software, semiconductors, electronic materials, and high-definition television. Other facilities concentrate on a single technology. For example, Kobe Applied Electronics Center, in Palo Alto, Calif., has focused its initial research activities on thin-film recording media for data storage.

The U.S. R&D activities of these overseas companies range from keeping an eye on technology and doing research into product applications to product customization, product design and development, and basic research. In the past, the facilities of foreign automotive companies, while nominally involved in R&D, did little or nothing of this nature. Instead, their main activities were, first, testing emissions for certification requirements and scanning the regulatory environment in general; second, evaluating the performance of their own and competitors' vehicles; and, third, monitoring U.S. automotive design and styling trends.

But in the last few years, more ambitious aims have come to the fore. Several of the facilities have embraced advanced concept design (for instance, the design of future vehicles), joint research, and vehicle prototype production. They now in addition get into parts and materials design and evaluation, research on key technologies (such as new materials and battery technology), and the development of parts suppliers locally. A recent example of such higher-value-added activities is the lead involvement by Toyota's U.S.-based Calty Research Design in the exterior design of the Lexus/Soarer Coupe.

As for the foreign operations doing electronics R&D in the United States, most of them conduct applied research, maybe developing new applications of existing technologies or products or tailoring products to customer needs. Some do both applied and basic research in electronics, the latter usually to only a limited degree. Nonetheless, there is a small but growing group of companies from overseas that have set up R&D facilities within the United States primarily for the purpose of conducting fundamental research. The most visible is the NEC Research Institute in Princeton, N. J., which performs long-term research in physics and computer sciences. Other electronics companies involved in some type of basic, long-term research in their U.S. laboratories are Canon, Philips, and Panasonic Technologies.

Non-U.S.-owned R&D laboratories in biotechnology for the most part fall into two groups: those that work on agribusiness, pharmaceuticals, and chemicals, and

those involved in research in recombinant DNA and monoclonal antibody technologies. The first group includes some of the largest foreign R&D laboratories in the country, and their owners include some of Europe's largest multinational firms. The DNA and antibody group, though, consists mainly of small laboratories with capitalization of less than $50 million. Switzerland's Ciba-Geigy, Japan's Ajinomoto, France's Rhone-Poulenc, and Germany's BASF all do biotechnological research in the United States.

REASONS TO INVEST. What forces impelled foreign companies to add to their R&D operations in the United States? A strong inducement is their inability to properly monitor technological developments in the country and to acquire its technology from abroad. Once, it was rare for companies elsewhere to need a U.S. R&D facility to utilize U.S. technology. They could keep an eye on developments from their home base, and they relied upon patent licensing and technology procurement to acquire whatever they wanted.

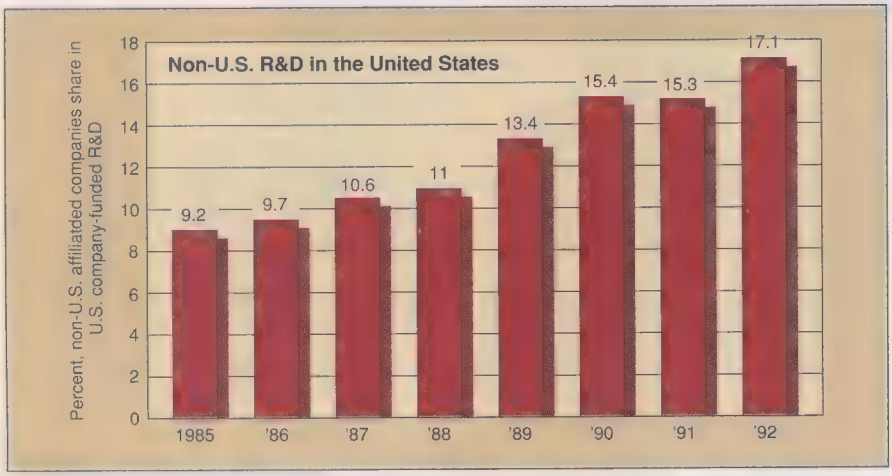
Some recent developments have persuaded these companies change their ways. One development was the growing complexity of new technologies and the greater speed of innovation. As a senior executive of a Japanese electronics company has expressed it: "Acquiring technology has become a more complex task in the United States. Without an actual presence [there], it is difficult for us to judge what technology is worth buying from U.S. companies. We built our R&D centers in the United States to establish a base that will help us make these decisions." An executive from a software company is of the same opinion, maintaining that the rapidity of technological change in the computer software industry dictated his company's presence "to keep up with day to day developments" in the dynamic U.S. industry.

The next development was a concern among foreign companies that the U.S. and other governments might restrict access by foreign nationals to the outputs of home research institutions, especially those financed by the government. The restriction may be governmental or commercial. An example of the former is the section of the U.S. Federal Technology Transfer Act of 1986 dealing with cooperative agreements between national laboratories and outside partners. The section requires national (U.S.) laboratories to "give preference to business units located in the United States and (in the case of a foreign company as a potential partner) to take into consideration whether or not such foreign government permits U.S. organizations to enter into cooperative R&D and licensing agreements."

On the commercial side, several companies have expressed apprehension about the continued willingness of companies to make their technology available to foreign buyers. This fear is one reason why several South Korean firms have invested in R&D operations in the United States.

The third change is the growth in the number of areas covered by strategic alliances between U.S. and other companies. In many cases, these alliances started out as a collaboration over sales and production and went on to become technology and R&D partnerships as well. Overseas companies involved in these alliances have established R&D centers in more than one state in order to work closely with their U.S. counterparts.

To illustrate, Nissan's new (and expand-



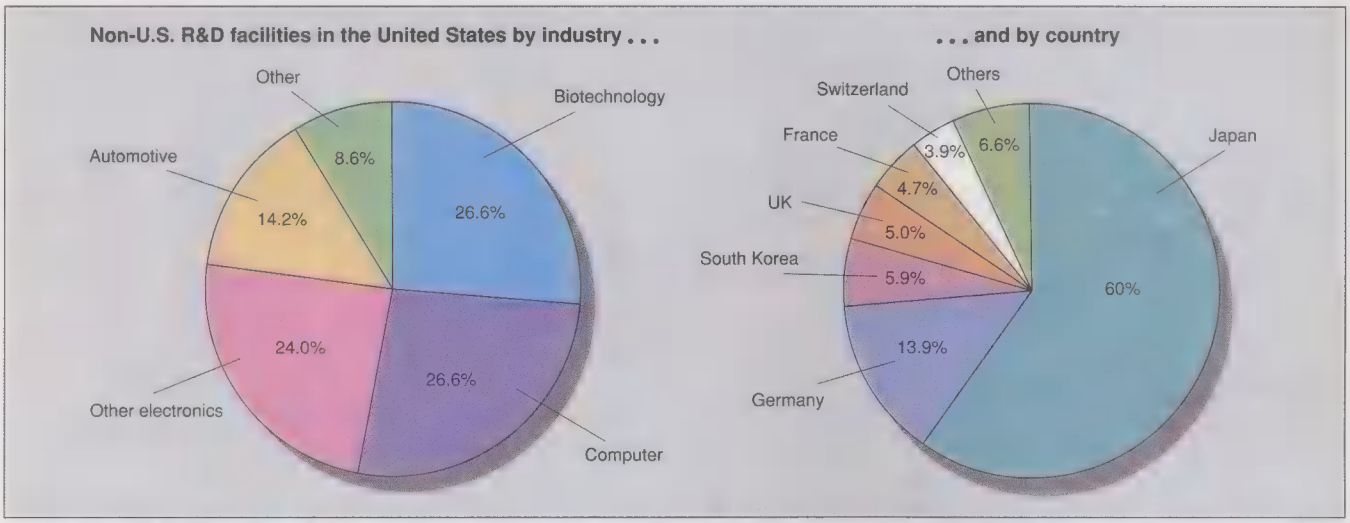
[1] Of all the R&D being performed within the United States, the share contributed by foreign-owned companies [above] has grown pretty steadily for about a decade. (Figures all supplied by authors Manuel G. Serapio Jr. and Donald H. Dalton.)

Largest foreign R&D centers in the United States

Company	Country	U.S. location	Industry	Staff size
Northern Telecom	Canada	Research Triangle Park, N.C.	Communications	1600
Wellcome Foundation	UK	Research Triangle Park, N.C.	Pharmaceuticals	1250
Glaxo	UK	Research Triangle Park, N.C.	Biotechnology	800
Honda	Japan	Ohio, California, Colorado	Automotive	800
Hoechst	Germany	Charlotte, N.C.	Biotechnology	580
Siemens	Germany	Boca Raton, Fla.	Communications	500
Hoechst	Germany	Summit, N.J.	Chemicals	450
Hoffman LaRouche	Switzerland	Nutley, N.J.	Chemicals	350
Toyota	Japan	California, Michigan	Automotive	350
Nissan	Japan	California, Michigan	Automotive	320
Philips	Netherlands	Briarcliff, N.Y.	Electronics, computers	285
Mazda	Japan	California, Ohio, Michigan	Automotive	213
Rohne-Polenc	France	Research Triangle Park, N.C.	Biotechnology	210
Ericsson	Sweden	Research Triangle Park, N.C.	Communications	210
Goldstar	South Korea	New Jersey	Electronics, computers	200

Source: Donald H. Dalton and Manuel G. Serapio, *U.S. Research Facilities of Foreign Companies*, U.S. Department of Commerce, 1993; Bob Williams, "The Same, Only Different," *The News Observer*, May 8, 1994.

[2] The 15 largest of the foreign R&D centers in the United States [right], like all the rest, are scattered throughout the country, although concentrations are evident in California, New Jersey, Michigan, and North Carolina.



[3] Foreign R&D activities in the United States are greatest in the biotechnology and computer industries, with other electronics research close behind. Of all the foreign firms involved, Japanese companies own the largest number of R&D facilities.

ed) U.S. technical centers have worked closely with both the Ford Co. in the United States and Nissan's R&D centers in Japan on the design, development, and production of Nissan/Ford's latest entry in the U.S. minivan market—the Nissan Quest/Mercury Villager.

The distinctly promising environment for research in the United States is another motive for non-U.S. companies to invest in its R&D. In the biotechnology industry, "taking advantage of a more favorable environment for research" weighed heavily in the decision of overseas firms to invest in R&D in the United States, according to this study. In a study of foreign biotechnology investments in U.S. operations, Emily Arakaki of the Department of Commerce observed that non-U.S. firms, particularly German companies, invested in U.S. biotechnology laboratories or acquired U.S. companies because of tight regulations on biotechnology research back home. A leading expert in biotechnology, Robert Fujimura of the U.S. Food and Drug Administration, attributes the excellent U.S. environment for research in his field to the leading-edge research now being conducted in the life sciences in the United States. This last fact he believes is largely owing to the substantial and sustained support of the U.S. government and the participation of top scientists and researchers from all over the world.

Two other components of the favorable U.S. research environment are a closer working relationship between academia and industry and the availability of engineers and scientists for employment. Several foreign R&D facilities have entered into collaborative arrangements with top U.S. universities, including Princeton, North Carolina State, and Stanford. These arrangements may include: employing professors from the universities as visiting researchers and their graduate students as research interns, funding professional chairs, sponsoring research, funding research conferences organized by the U.S. universities, and conducting joint R&D with them.

WARY OF SHORTAGES. The desire to employ U.S. scientists and engineers anticipates possible shortages of these professionals in the electronics and automotive industries in Japan. Several of the Japanese companies in the study indicated that their U.S. R&D facilities were a hedge against this prospect. It has been projected by Sally Tully and K. Yamamura in "Japan's Technological Capabilities and its Future" [see To Probe Further, p. 30] that the demand for scientists and engineers in Japan will double between 1990 and 2000 while, according to the U.S. Bureau of the Census, the growth in the supply of these men and women will slow from an annual growth rate of 12.6 percent during 1985–90 to a mere 2.4 percent during 1995–2000. Moreover, employing U.S. scientists and engineers has also given overseas companies greater flexibility. Unlike many of their Japanese and European counterparts, highly trained U.S. scientists and engineers are frequently willing to work on a consulting or project basis. Consequently, the foreign R&D laboratories can assemble a group of U.S. experts to work on a project without having to hire them for the long term, as is customary in their home countries.

Some companies studied cited the desire "to support their U.S. manufacturing subsidiaries" as another factor in favor of investing in U.S. R&D. Since 1980, Japanese and European manufacturing investments in the United States have risen steeply. For example, Japanese investments of this type increased more than sevenfold, leaping from $2.7 billion in 1985 to about $20 billion in 1993. And Japanese manufacturing plants with U.S. locations soared from 240 all told in 1980 to about 1600 in 1993.

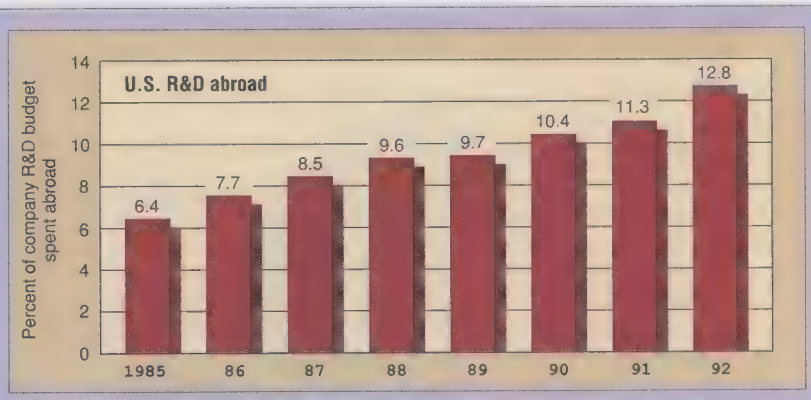
Along with that expansion, though, non-U.S. companies discovered that transplanting production overseas, especially if it required local content and product or production process localization, entailed an effort at adaptation and product or process redesign and re-engineering. In turn, this discovery has prompted the companies to invest in U.S. R&D facilities.

Foreign companies have relied on these R&D operations for help in several areas: shortening the cycle between product design and development, as well as between product development and engineering; monitoring design and styling trends in the United States; and working closely with U.S. customers in tailoring products to their specifications.

To illustrate one of the most important roles played by a U.S. R&D facility on behalf of its overseas owner, it is worth quoting at length a statement made by an executive of a large Japanese automotive company. In the course of one of the interviews conducted for the study, he said: "Prior to establishing an R&D center in [the United States], our engineers in [the U.S. plant] had to work with the R&D division and technical centers in Japan. We were sending faxes to each other all the time and our engineers took many trips between Japan and the United States. The process of developing and producing a car for the U.S. market or correcting an engineering problem was very time consuming. We have eliminated this lengthy process by establishing a U.S. technical center [in close proximity] to our U.S. plant, sales office, and suppliers in the United States. We expect to shorten the time needed for concurrent design and development, concurrent development and engineering, and working on design and engineering issues for our vehicles in or near production."

SOME SITES. Foreign laboratories are to be found in 23 states, but mainly in certain areas. European firms initially established R&D facilities on the East Coast and are moving west,

U.S. R&D activities overseas



Of recent years, the amount of R&D being performed by U.S. companies on other than their native soil, like the R&D of non-U.S. companies being done in the United States, has been growing, although at a somewhat slower rate.

Companies from Japan and Europe are not the only ones to recognize a good investment when they see one. U.S. companies, too, are stepping up their overseas R&D operations [see figure]. Expenditures on all R&D by U.S.-based multinationals have more than doubled in less than a decade, going from $3.6 billion in 1985 to $10 billion in 1992. R&D expenditures by American companies abroad account for 12.8 percent of all private U.S. expenditures on R&D, up from 6.4 percent in 1985.

Direct investments by U.S. multinational companies overseas are nothing new. For many years now, firms like IBM, Union Carbide, Corning Glass Works, and Caterpillar have operated R&D facilities abroad. A pioneering study of U.S. R&D done in other countries by U.S. multinational companies was produced by Robert Ronstadt in 1977. He noted that in 1974 IBM Corp. spent about $200 million (roughly 30 percent of its R&D budget) on overseas work of this kind. Other companies, such as Otis Elevator, CPC International, and Exxon, spent 50 percent, 38 percent, and 25 percent of their R&D budgets, respectively, on the same endeavor during the same period.

In more recent years, the overseas R&D investments of U.S. multinationals have ballooned. Nowhere is this more evident than in Japan. A total of 79 U.S. R&D facilities, employing over 5000 people, were identified in that country by a 1994 report by the Japan Technology Program of the U.S. Department of Commerce. Of these facilities, more than half were either established or acquired within the last seven years. Some of the new establishments include centers overseen by U.S. companies such as Apple Computer Inc. and Texas Instruments Inc.. General Motors Corp. not too long ago expanded its Japanese technical facility, GM Asian Technical Center. Ford Motor Co. has a small R&D operation at its location in Hiroshima and reportedly is looking into expanding the amount of R&D it does in that country. Other companies with a longstanding R&D presence in Japan include IBM, Caterpillar, NCR, and Digital Equipment.

—M.G.S. Jr. and D.H.D.

whereas Japanese companies began on the West Coast and are moving east.

California's Silicon Valley has attracted many facilities conducting R&D in computers, software, semiconductors, and other electronics. Important clusters of foreign R&D centers in electronics also exist in New Jersey, North Carolina (in Research Triangle Park), and Boston. The strongest influences on choice of location for the electronics R&D facilities, the study found, are availability of scientists and engineers, nearness to customers, and proximity to U.S. universities, such as the Massachusetts Institute of Technology, and to other private R&D laboratories.

Automotive companies, both U.S. and non-U.S., have chosen the Los Angeles Metropolitan Area and other parts of Southern California as the place to put design studios. There are 13 such studios in Southern California, seven being Japanese, three being American, and the other three being Swedish, German, and South Korean.

In addition, several technical centers belonging to foreign automotive companies are situated near Detroit, Mich. The firms picked these locations for access to skilled automotive engineers, automotive parts suppliers, the Big Three U.S. automotive companies, and the Environmental Protection Agency (EPA).

The largest concentrations of foreign facilities for biotechnology R&D occur on the East Coast and in the Midwest. Because many of these facilities were acquired, their adoptive parent companies had no input in the choice of their original locations. However, those companies in this study that did select their facilities' sites cited the availability of scientists and researchers plus proximity to customers, suppliers, and other R&D facilities as favorable factors.

Overseas companies are likely to further increase their R&D investments in the United States. For example, the South Korean government recently announced a plan to promote the globalization of R&D by South Korean companies. As a result of this ambitious policy, those companies are expected to establish or acquire more R&D facilities in the United States during the next decade. More than half of the R&D companies interviewed for this study also said they had plans to expand their U.S. R&D operations. This prospect raises several questions for U.S. companies engaged in R&D.

SOME ISSUES. First, to what extent will foreign R&D facilities compete with U.S. companies for such resources as top scientists and researchers or new engineering graduates? The recruitment practices of the foreign facilities indicate a willingness to bid aggressively for top talent, while as employers, they are rated by most U.S. researchers and engineers as being as attractive as their U.S. counterparts.

Next, how does R&D in foreign-owned and U.S.-owned research facilities compare? What are their relative strengths and weaknesses? What can the U.S. R&D facilities learn from these other R&D facilities?

Finally, what implications does the growth of foreign R&D activity within the United States hold for technology transfer? Will the foreign presence promote a one-way transfer of technology (from the United States to the rest of the world) or a two-way technology transfer? This question is of interest not only to industry leaders and practitioners but especially to U.S. government officials who shape technology and R&D policies.

TO PROBE FURTHER. A listing of foreign R&D facilities and a discussion of direct foreign investments in R&D in the United States appear in *Research Facilities of Foreign Companies,* by this article's authors (NTIS PB 93-134328, Japan Technology Program, U.S. Department of Commerce, 1993). A 1994 report from the same source and by one of the same authors (Manuel G. Serapio Jr.) is *Japan–U.S. Direct R&D Investments in the Electronics Industry,* NTIS PB 94–127974; it compares U.S.-Japan cross-border investments in this area, computers and ICs included.

Sully Taylor and K. Yamamura's "Japan's Technological Capabilities and its Future" is in *Technological Competition and Interdependence: the Search for Policy in the United States, West Germany, and Japan,* ed. G. Heiduk and K. Yamamura (University of Tokyo Press, 1990), pp. 43–44. ◆

ABOUT THE AUTHORS. Manuel G. Serapio Jr. is assistant professor of international business and management at the University of Colorado in Denver. His research on the internationalization of R&D has been published by the U.S. Department of Commerce and in such journals as Management International Review *and* Research Technology Management.. *He consults and conducts programs in international business for IBM, Schuller, Coors Brewery, Ssangyong Corp., and other multinationals.*

Donald H. Dalton is a research economist at the business issues analysis division of the Commerce Department. He has published widely in the field of international R&D, foreign direct investments in the United States, and international technology transfer.

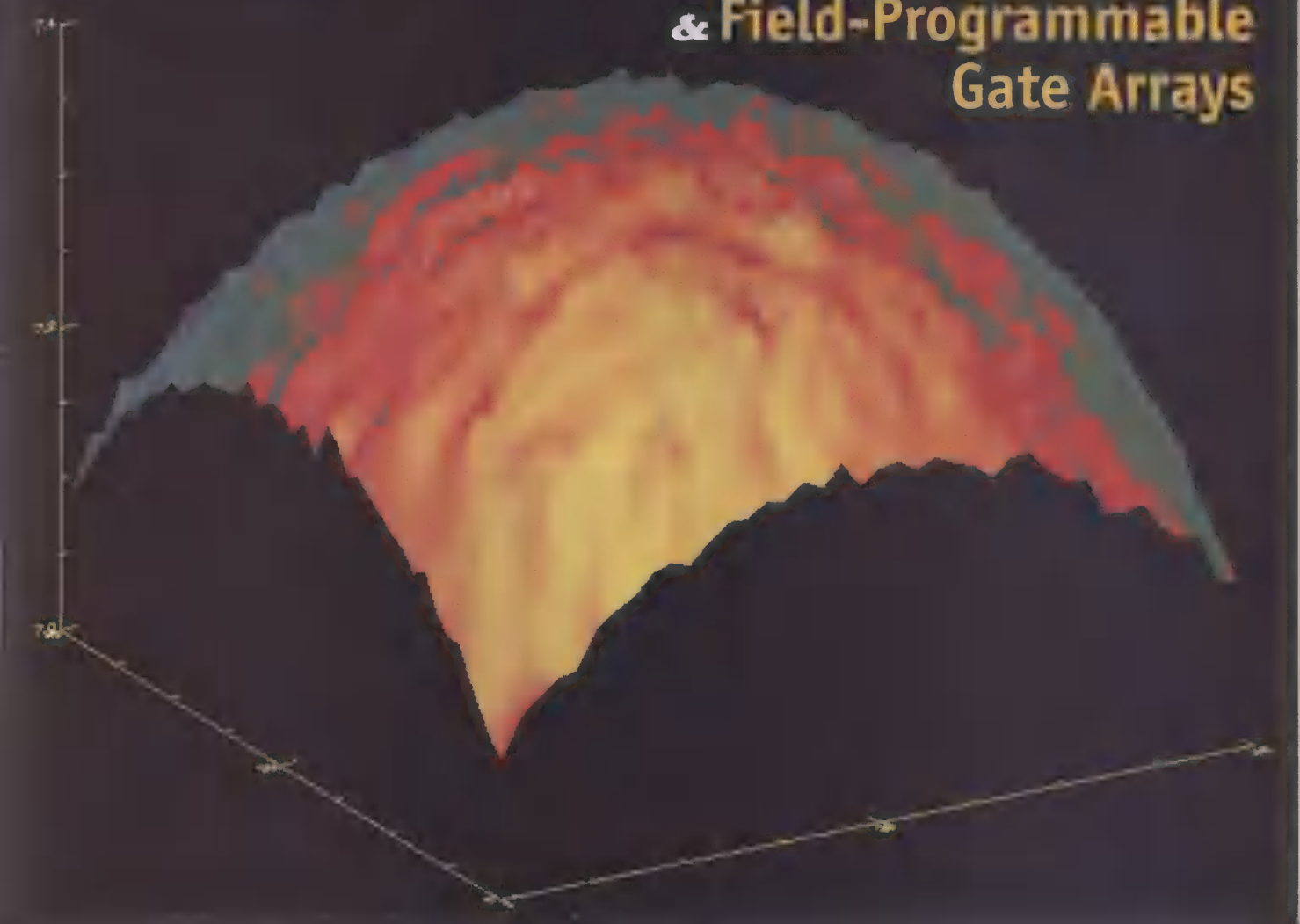
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Focus Report:

SOFTWARE

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0.303	0.0869854	0.566156	10.9343
0.328	0.0833859	0.704584	10.1044
0.353	0.0801771	0.594178	9.54882
0.378	0.0774072	0.675732	9.21645
0.403	0.0748866	0.586839	9.00972
0.428	0.0726882	0.626687	8.92038
0.453	0.0706936	0.544622	8.92778

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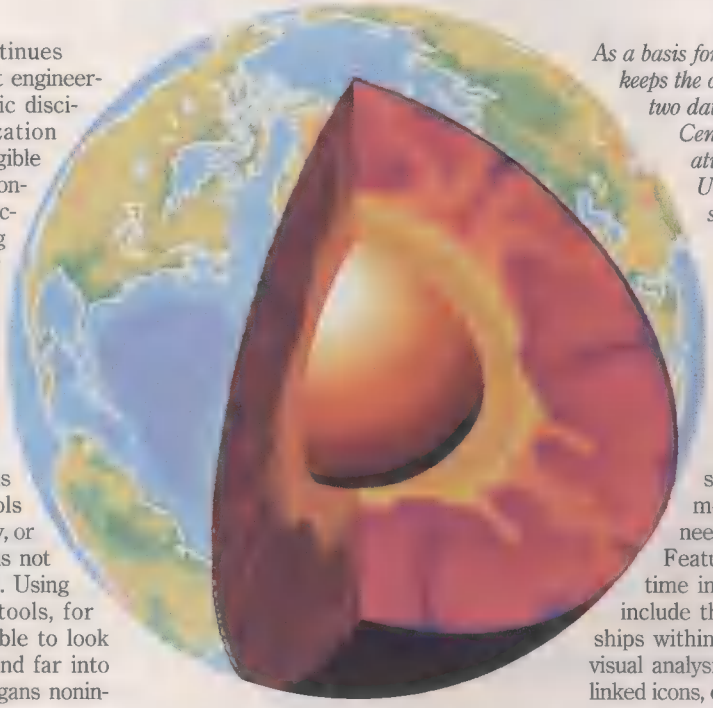
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Circle No. 42

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As a basis for depicting the magma flow that keeps the continental plates uneasily astir, two datasets were used by the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign. One dataset supplied the varying elevation of the earth's surface; the other, convection data (simulated) of the earth's molten mantle. IDL software "rendered" the three-dimensional image.

Research Systems Inc.

Mathematics continues to energize most engineering and scientific disciplines. Visualization makes the math results intelligible to the human eye and brain. Concurrently, advances in microelectronic circuitry, now teetering on the deep-submicrometer brink, bring a fresh look to IC design automation. Astoundingly, FET feature sizes and channel lengths can now measure less than 0.5 micrometer, versus 1 μm only four years ago and 5 μm over 10 years ago.

In general, math applications and visualization software tools are becoming more user-friendly, or are opening up new applications not even imagined a few years ago. Using mathematical and graphical tools, for example, scientists are now able to look deep inside the human body and far into space—to scrutinize human organs noninvasively, and to explore the plasma around the sun. In electronic design automation, evolving tools for designing so-called deep-submicrometer circuits are eagerly awaited by the IC design community.

In a departure from previous focus reports on engineering and science software, this one, the fifth, brings together, for the first time, math and visualization, along with electronic design automation. Symbolic and numerical math software is the topic of the first article, plus a table of representative software packages. Most of the serious math programs give the engineer a choice of 700 to 3000 functions, and almost all the programs have two- and three-dimensional plotting capability. Linkage to other programs, as well as the availability of toolboxes for specialized disciplines—control theory, signal processing, and neural networks, for example—are among other noteworthy trends [p. 35].

The second article, "Visualization: the look of reality," addresses research trends in that field. One of the larger issues explored here is how to display multivariate states of behavior in a comprehensible manner [p. 48].

Meanwhile, a wealth of software is readily available with which engineers and scientists may analyze and view data in a wide range of disciplines, according to the third article. These disciplines include oil and gas exploration, electronics, telecommunication system design, and civil, biomedical, and mechanical engineering, to name but a few [p. 57]. Features to be found for the first time in the recent crop of software include the ability to explore relationships within multivariate data, capturing visual analysis sessions in "work maps" of linked icons, object-oriented volume rendering, and programming for application development. These and other features are reflected in packages from the more than 60 companies included in the second table.

Incidentally, discounts for the software in both tables are often available for educational institutions, and readers are encouraged to check with the vendors. Entries in both tables were checked for factual accuracy by the vendors.

In order to design electronic circuits with sub-half-micrometer features, future electronic computer-aided design tools will have to feature more accurate transistor models and more efficient timing and power analysis capabilities than those available up till now [p. 84]. In another design automation activity, tools for designing field-programmable gate arrays (FPGAs) offer an increasing variety of design entry strategies, as well as FPGA-specific logic synthesis [p. 88].

For convenience, uncommon terms occurring in the report are explained in the list of defining terms [p. 34]. Last of all come sources for further study [p. 95].

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To probe further 95

Cover: Using PV-WAVE Personal Edition software, engineers and scientists can analyze data by creating a 3-D mesh surface plot. Color can be used as a fourth dimension in which each hue represents a different value of a variable.

Visual Numerics Inc.

Gadi Kaplan Senior Technical Editor

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Defining terms

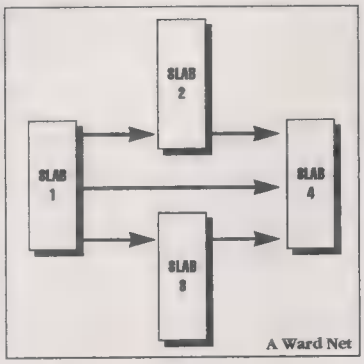
Application Library: a Mathematica package defining a set of functions for a specific application area; it is more tutorial than a toolbox [see below] sand more comprehensive than function packs [also see below].
Cell: all the information under a heading in an outliner program.
Channel-connected network: a network of transistors connected through their drains and sources only; connections to transistor gates are used to break the net into stages. If the design has no pass transistors, the channel-connected stages correspond to the logic cells employed by designers.
Eigenvector: a vector representing characteristic directions at a point with a result field.
Electronic Handbook: a set of Mathcad documents containing formulas and solved problems from various published handbooks and that allow a user to vary the parameters in each solution.
Event-driven simulator: one that, when performing computations, recognizes only those voltage changes that equal or are greater than a predefined value. An event in this context is a predefined minimum change in the voltage of a node.
False path: one never exercised during circuit operation. Because static analyzers model not functionality but only timing, they tend to include such paths in their output reports.
Function Pack: a collection of Mathcad documents with worked solutions that are very tutorial, but not comprehensive, taken from various areas of engineering.
Hyperstreamline: visualization of a tensor field by means of three orthogonal eigenvectors. The process involves sweeping a finite-size geometric primitive along the path of one eigenvector, while stretching it in the transverse plane under the combined action of the other two orthogonal eigenvectors.
Interactive steering: employing feedback from visualization so as to alter the course of some computing process—for instance, seeing the results of an analysis, and then interactively altering the analysis model.
Isosurface: a surface of constant value within a three-dimensional scalar field.
Logic synthesis: the process of generating an optimized gate-level netlist description of a logic design from a higher-level structural description.
Look-up table: precharacterized values of transistor parameters, typically gate-capacitance, diffusion capacitance, body bias, and current-voltage curve values. The characterization is performed using a Spice-like circuit simulation for most of the transistor sizes used.
Macros: schematics that contain primitives and other macros to implement pre-defined functions such as counters, shift register, and decoders.
Marching Cubes: an algorithmic approach to computing isosurfaces within a volume by examining individual volume elements (voxels) for intersection with an isosurface.
M-file: an ASCII file that is written in the Matlab language and capable of being loaded into Matlab; users may access new functions without seeing the function definitions.
Notebook: a Mathematica file in the format of an outliner (see below).
Outliner: a special form of word processor. Its user selects a line of text and declares it to be a heading, or a subheading, or a piece of text under a subheading, with everything that comes under a heading counting as a cell. Each cell can be either collapsed, so that only the heading line is seen, or expanded, so that everything may be seen. Consequently, a user may alternate rapidly between the details and an overview of the text.
Package: the name given to one or more ASCII files written in the Mathematica language; a package also defines a context for the Mathematica functions it defines, so that many packages can be loaded without conflict.
Primitives: symbols that are directly recognized by the implementation software and which usually correspond to a logic resource in the target field-programmable gate array; examples are input-output pads, logic gates, flip-flops, and buffers.
Slack: the additional time that a signal can be delayed on a node without increasing the delay over the longest path. A negative slack is always part of any timing error (or violation) report produced by a static timing analyzer.
Stream polygon: a planar polygon at a point within a vector field that represents vector or multivalued data by means of attributes like color, shape, and thickness.
Stream tube: a tube-like shape formed when stream polygons are connected along a streamline, or a path through the vector field.
Toolbox: one or more M-files that define new Matlab functions in specific application areas, such as signal processing or control systems. Toolboxes are typically more comprehensive than Mathcad documents and less tutorial than Mathematica application libraries.
Volume field: a three-dimensional distribution of one or more data variables, commonly expressed as a regular array of the discrete unit elements known as voxels [see below].
Volume rendering: any of a number of voxel-based techniques used to generate imagery of an overall volume field. A volume-rendered image may, for example, show varying colors and varying degrees of translucency to indicate the nature of the overall field.
Volume slicing: employment of a computed plane to cut away part of a three-dimensional model, either to reveal its interior parts or to disclose results displayed on the cut face.
Voxel: the basic unit of a discrete volume space, defined as a cube connecting eight adjacent vertices of an ordered array of point locations in three-dimensional space.

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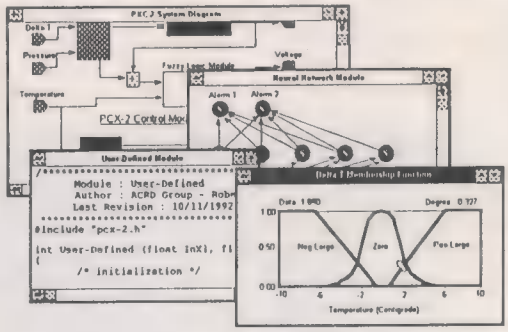
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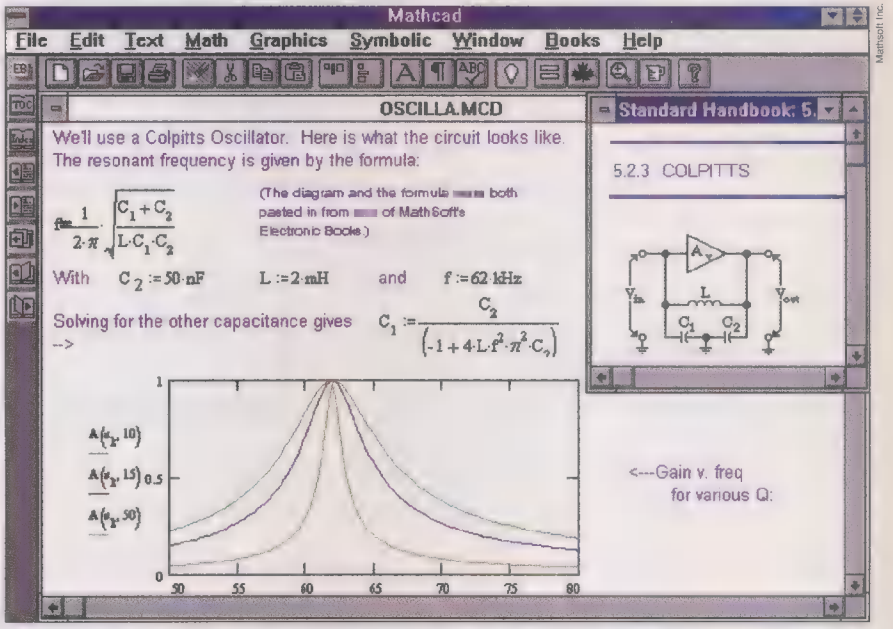
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Mathematical power tools

Swift solutions to engineering problems recompense the investor in a modern math package for its cost and the time spent learning to use it



[1] In presenting a Mathcad Colpitts oscillator solution, the Mathcad window shows several features of the Mathcad front end. Text can be inserted to describe the problem. Pictures can be pasted into the document just as the Colpitts schematic has been included. Variables can be solved for, as in the case of : =, or printed, as is the case with just =. Finally, plots based on the defined equations can be displayed.

Software for doing mathematics sounds like something that all of us needed in college. Certainly the programs to be described here can solve differential equations and reduce many integrals to simple expressions—a dream come true for mathematicians, but surely no more than neat widgets for engineers. The fact of the matter is more impressive: math programs empower engineers in two ways, by making mathematics more accessible to them, and by making them better able to communicate their results to other people.

Any engineer who has a C, Fortran, or Basic programming language on his or her computer should consider buying a math software program. The reason is that over the long haul the program will save its user time and money. For one thing, most math software programs employ a high-level language that is closer to typical math expressions than a low-level language, such as C. For another, a good many of these programs are interactive, like Basic, but at the same time make it possible to save functions for later reference, like C. In addition, math software generally incorporates excellent two- and three-dimensional graphics functions.

LEARNING TO LOVE. All the same, the typical engineer does not spend a large part of the day solving math problems. But vendors have equipped the latest generation of math software programs with interfaces that engineers can learn to love. The interfaces come in several forms, but the most outstanding of them allow engineers to combine text (such as a problem description), pictures (such as a schematic), analyses, and graphics. Of course, math programs can also import measured numbers. Work goes far more smoothly when a problem is solved and documented with a single program.

The current focus of attention among software vendors is on giving engineers more of what they want. The larger products, such as Macsyma, Maple, Mathcad, Mathematica, and Matlab, go much further and try to give engineers *everything* they could possibly want.

These days, the largest math programs integrate symbolic and numerical analysis with user-friendly interfaces plus a programming language, application-specific packages, and an ever-increasing set of functions. Moreover, dynamic data exchange (DDE) is included for IBM PCs and compatibles.

For some programs, such as Derive or Math Advantage, all that was needed was to increase the usable memory or number of functions. The serious math programs in general can showcase 700 to 3000 functions. And all but a few have 2- and 3-D plots available. Still more ambitiously, such programs as Magma and Mathematica escort the engineer beyond the bounds of elementary algebra to explore groups, rings, fields, and various other aspects of abstract algebra.

Applications have become the chief growth area for mathematics programs. Engineers as lovers of engineering are in clover at having 700 functions and more to browse through; but as engineering team members, they need to get their work done.

To help them get down to work, Matlab has had Toolboxes [see Defining terms, p. 34], Mathcad has had Function Packs, and now Mathematica has Application Libraries. Macsyma, moreover, is selling an automatic solver of partial differential equations, called PDEase, to assist engineers with some of the toughest problems they face.

Third-party add-ons have been a sluggish part of the math software market. However, third parties could play a major role in the future of all programs in this area, just as they did in the case of Auto-Desk's Autocad product. Autocad is a sophisticated drafting program that runs on personal computers. But because it uses the familiar Lisp language for automating tasks, and an ASCII interchange file, many third parties have been induced to extend Autocad's capabilities.

It is widely believed the extensibility of Autocad is at least one of the roots of its success, and many math software vendors are hoping that their products' extensibility will make them successful, too. After all, math solutions are made to be shared, and it is customary for engineers to share

Alfred Riddle Macallan Consulting

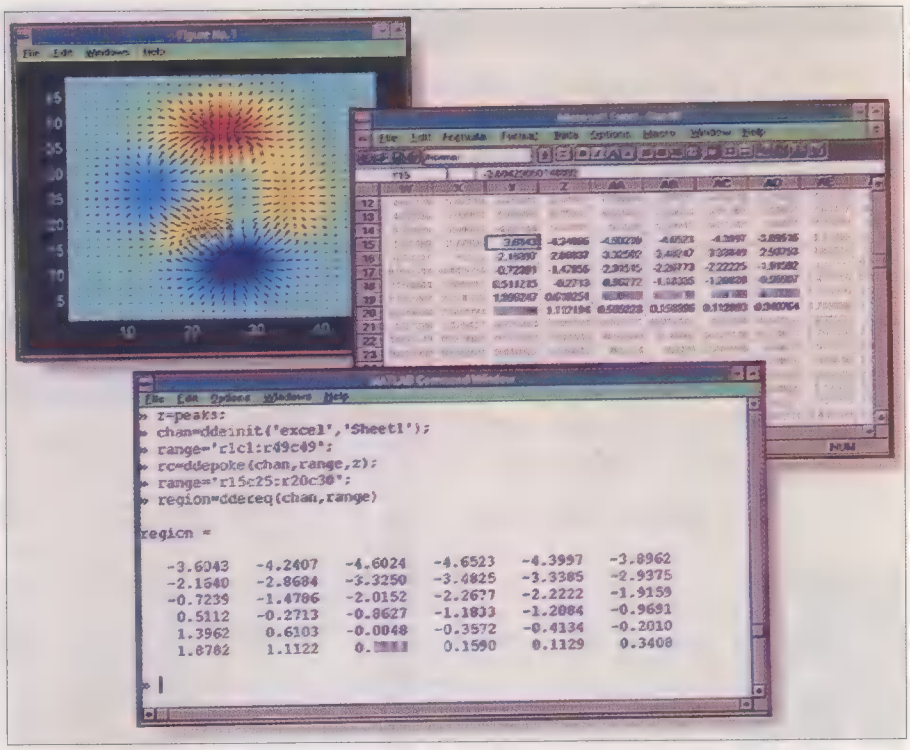
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their programs with other engineers.

Meanwhile, code libraries, such as those sold by Numerical Algorithms Group and IMSL, remain a solid part of the math software market. These code libraries allow engineers to build custom solutions for research or production. The price exacted for using the libraries is the toil entailed by low-level languages such as Fortran and C, which require a lot of programming work besides just writing out the solution algorithm. Similarly, custom application generators, such as IDL and ESPro, try to leverage an engineer's knowledge through a high-level language and interface builder, thereby avoiding the extra work of a low-level language.

RECENT HISTORY. Mathematical software has become part and parcel of personal computing for engineers. In the not-so-distant past, engineers used plotting programs and spreadsheets and did math mainly on calculators, or programmed it in Basic. Whereas research scientists might have had access to Macsyma or Matlab, mainstream engineering looked upon dedicated symbolic and numerical math programs as expensive and hard to justify.

Then the late 1980s witnessed the appearance of two major agents for change in mathematical software, namely, Mathematica and Mathcad. Mathematica was



The MathWorks Inc.

[2] Here, a Matlab solution is linked to the Excel spreadsheet through dynamic data exchange (DDE). The Matlab workspace window [bottom] has captured data from the Microsoft Excel window [right]. The plot is of a large dataset that has been put into Excel through DDE.

Symbolic and numerical math software

Name	Platforms	Package description	Comments	Related packages
Analytica, Nedlands, Australia; (61+9) 386 5666; fax, (61+9) 386-5666; e-mail, analytic@earwax.pd.uwa.edu.au				
InterCall Circle No. 131	Macintosh: $275+ Unix workstations: $275+	A Mathematica add-on that simplifies access to numerical routines such as IMSL, Numerical Algorithms Group (NAG), Linpack, RKSUITE, Minpack, Itpack, SSL2, and any user-defined Fortran or C code	Requires Mathematica, Mathlink, and TCP/IP	Mathematica, IMSL, NAG, Linpack, RKSUITE, Minpack, Itpack, SSL2
Aptech Systems Inc., Maple Valley, WA; 206-432-7855; fax, 206-432-7832; e-mail, info@aptech.com				
Gauss Circle No. 132	Macintosh: N.A. IBM-type PC: $995+ Unix workstations: $1995+ Other: Convex, call vendor	Math and statistical analysis environment based on fast, extendable, interactive array language; new version adds speed, 32-character symbol names and string arrays, improved file I/O, 2-D fast Fourier transforms, and version for Pentium PCs	Has hundreds of math functions, including linear algebra routines, 2- and 3-D publication-quality graphics with color PostScript outputs	Applications packages in Gauss cover analyses in statistics, econometrics, engineering, simulation, signal processing, behavioral studies, and more
Civilized Software Inc., Bethesda, MD; 800-672-6522, 301-652-4714; fax, 301-656-1069				
MLAB Circle No. 133	Macintosh: $1995 IBM-type PC: $1495 Unix workstations: $2995 Other: NextStep, $2995	Advanced math and statistical modeling system for a wide range of problems	Has over 400 built-in functions including many unusual ones like Voronoi diagrams; solves and curve-fits differential equations; Provides 2- and 3-D graphics plus color PostScript output	—

Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Computational Algebra Group, Sydney, NSW, Australia; (61+2) 692 3338; fax, (61+2) 692 4534; e-mail, magma@mathssu.oz.au				
Magma 1.01 Circle No. 134	Unix workstations: $1000+	Integrated system for solving computational problems in algebra, number theory, geometry, and combinatorics; provides an imperative-style programming language with powerful set-theoretic and functional subsets and a C kernel containing the principal algorithms for modules, rings, groups, fields, graphs, and codes	Takes a structural view of mathematics, giving the concepts of structure (magma) and homomorphism first-class status in the language	As the more general successor of the group theory package Cayley, Magma incorporates KANT, Pari, nauty, PERM, and other algebra packages using its software bus
Future Graph Inc., Southampton, PA; 215-396-0720; fax, 215-396-0724				
F(g) Scholar Circle No. 135	Macintosh: $295 IBM-type PC: $295 Unix workstation: coming in 1995	Combines engineering and scientific spreadsheet, technical graphing, and a graphing calculator with over 500 functions and analysis tools	WYSIWYG spreadsheet; user- defined functions, constants, variables, extensive statistics for such areas as DSP and differential equations; also suitable for writing lab reports and other engineering documents	Combines data management, numerical capabilities, and ease of use of spreadsheets with math and computational tools for engineers; resembles Excel, but specifically designed for engineers
Harmonic Software Inc., Seattle, WA; 206-367-8742; fax, 206-367-1067; e-mail, harmonic@world.std.com				
O-Matrix 2.0 Circle No. 135	IBM-type PC: $95+	High-performance visual data analysis; includes extensive numerical analysis capabilities, a simple matrix language with integrated debugger, and publication-quality interactive graphics	Powerful windows interface simplifies data analysis; complete 32-bit application	O-Matrix 2.0 for Windows is an extension of O-Matrix for DOS
Macsyma Inc., Arlington, MA; 617-646-4550; fax, 617-646-3161; e-mail, petti@macsyma.com				
Macsyma 2.0 Circle No. 136	IBM-type PC: $299; after Nov. 31, 1994, $349 Unix workstations: $999+ Other: VMS, $999+	Powerful and comprehensive symbolic, numerical and graphical math program; adds animated graphics, notebooks, extended linear algebra, more speed and solution methods for partial differential equations	Solves huge range of math problems; has notebook documents, extensive online help, and intuitive interface	PDEase finite-element analysis software
Macallan Consulting, Milpitas, CA; 408-262-3575; fax, 408-262-3575; e-mail, alfy@cup.portal.com				
Nodal Circle No. 137	Macintosh: $395 IBM-type PC: $395 Unix workstations: $395	Object-oriented linear circuit analysis; includes transmission line, inductor, and capacitor design functions, and plotting functions, such as Bode plot, Smith chart	Can modify source code in Mathematica language	—
MathSoft Inc., Cambridge, MA; 617-577-1017; fax, 617-252-5670; e-mail, ekoup@mathsoft.com				
Mathcad 5.0 for Windows Circle No. 138	IBM-type PC: $99.95	General-purpose software for numerical and symbolic calculations; documents results; 2- and 3-D graphics; DDE and OLE links	Windows-based application lets users work with an electronic whiteboard and automatic calculation	—

Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Mathcad Plus 5.0 for Windows Circle No. 139 (second of two items)	IBM-type PC: $299.95	Enhanced version of Mathcad	Differential equation solvers, advanced matrix functions, symbolic and numerical calculation power; users may write own C and C++ functions	Power can be enhanced with over 50 live electronic books, add-ons, and function packs
MathSolutions Inc., Chapel Hill, NC; 919-967-9853; fax, 919-967-9853; e-mail, mathtensor@wri.com				
MathTensor Circle No. 140	Macintosh: $570 IBM-type PC: $570 Unix workstations: $800 Other: Convex $3000	Adds tensor analysis, programming and differential forms capabilities to Wolfram Research's Mathematica	Adds more than 250 functions and objects to Mathematica	—
MGA Software, Concord, MA; 508-369-5115, ext. 252; fax, 508-369-0013				
Optdes Circle No. 141	Macintosh: $2500 IBM-type PC: $3500 Unix workstations: $4000+	A design synthesis and optimization tool for investigating multidimensional design space to identify feasible or optimal designs; math algorithms adjust all variables to improve objectives and satisfy constraints	Menu-driven; allows sensitivity analysis; choice of five optimization algorithms	Part of family for the analysis, modeling, and simulation of dynamic systems
ACSL Model Circle No. 142	Macintosh: $3950 IBM-type PC: $3950+ Unix workstations: $8000+	A complete environment for simulating, modeling, and analyzing systems described by time-dependent, nonlinear differential equations or transfer functions	Has powerful instructions, including simulation operators and commands tailored for continuous simulation; has a graphical user-interface and block-diagram front-end	Part of family for analysis, modeling, and simulation of dynamic systems

designed to be comprehensive, Mathcad to be user friendly. Both programs came out to a fanfare of marketing efforts and with alluring capability per dollar. They awoke a sleepy math software market, and competition has flourished ever since. Best of all, engineers are now realizing that math software is not a luxury, but a necessity in their line of work.

GIVE ME A LEVER. Math programs grew out of a desire to render esoteric skills accessible. Matlab, for instance, started as an interface to the powerful matrix manipulation routines developed in the Linpack and Eispack projects. Eispack is a collection of Fortran subroutines, developed in the early 1970s, under National Science Foundation funding, for solving matrix eigenvalue problems. Linpack is a collection of Fortran subroutines for solving linear systems of equations. J.J. Dongarra and C.B. Moler were among the principal authors of both projects.

Much of the code developed by these projects has found its way into the library of software sold by IMSL. Linpack and Eispack are part of public domain software available through the Internet at Netlib [see "Internet and Netlib," p. 41].

Macsyma and Maple were written to solve symbolic differential and integral equations. And Mathematica had its origins in the algebraic manipulation of quantum mechanical expressions. All of these programs, as already noted, were designed to put the math knowledge of specialists at the disposal of working people. Unfortunately, the typical engineer left advanced math behind at the university, and most of the early math programs simply did not make advanced math accessible enough to be worth buying.

Mathcad changed the equation for math software. It mimicked a chalkboard, offered enough mathematics to be useful but not confusing, and was affordable enough to try. Even today, limited versions of Mathcad sell for $100 or less.

The interface has been the key to computer software success for computers. If a program appears fun to use, and is cheap enough, people will buy it. Many engineers have bought Mathcad and liked the textbook look of their equations and graphs spread over a page. Many teachers, too, have incorporated Mathcad into their classroom presentations, because the software was inexpensive and the results looked like their chalkboard.

Programs such as Mathematica and Matlab have also wrestled with the thorny problem of interfacing with the user. Because Mathematica's mission was to be comprehensive, its developers at Wolfram Research Inc. stood by its command-driven interface, but were inspired to incorporate an outliner in the interface. The company was the first to enable users to organize text, graphics, computer output, and pictures in a single "notebook." If in addition the "notebook" had collapsible cells, like an outliner, no confusion would arise during the process of putting a lot of information into a single document. The "notebook" concept comes very close to an ideal technique for solving and documenting a problem solution.

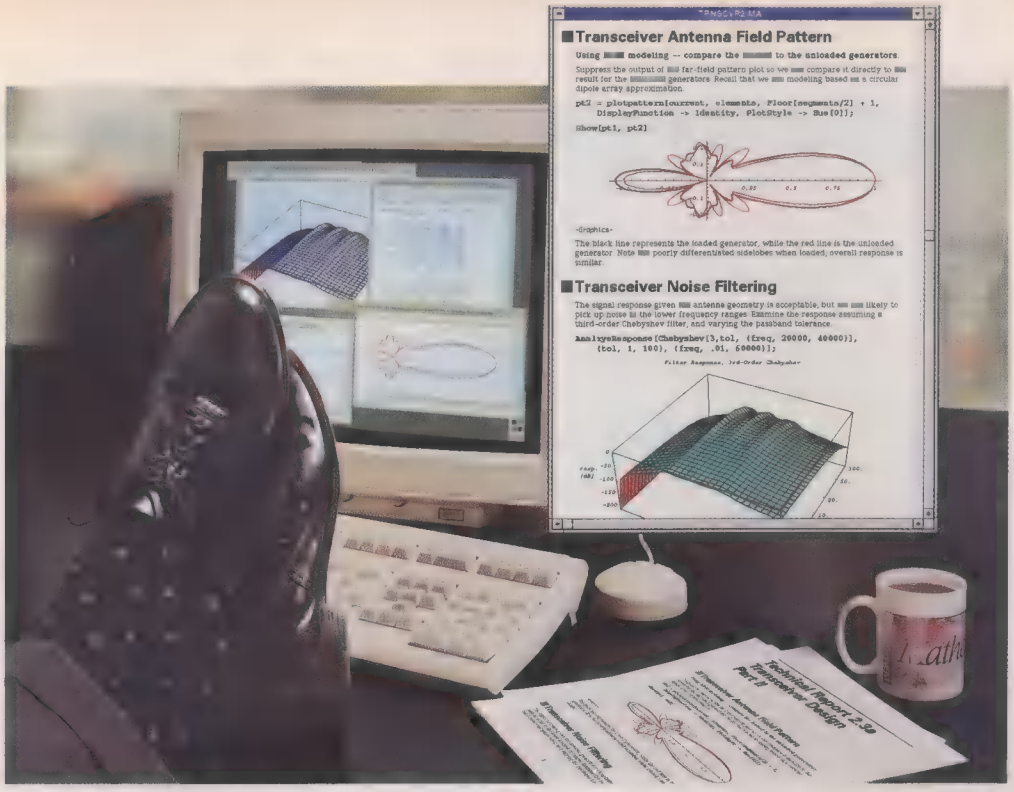
Matlab, meanwhile, extended its user interface through a block diagram editor. The standard Matlab program consists of separate windows for editing text and displaying graphics. The Simulink program links a third type of window to Matlab, a block diagram editor. Because engineers do so much documentation, and so much thinking in terms of block diagrams, the Simulink interface is congenial and a natural success. Linking to new capabilities has become the latest trend in this kind of software.

Once an engineer buys a math program, she or he discovers what the program cannot do. So companies expand their programs.

One of the easiest ways to do this is to link a program to a second one having the capability the first one lacks. Waterloo Maple Software has led the way in allowing links to other programs. In fact, both Mathcad and Matlab use part of its Maple symbolic engine.

Besides expansion there is extensibility, also a big part of math software. Mathcad and Matlab now have dynamic data exchange. Mathcad in addition has links to C functions.

These extensions matter to Mathcad because its intrinsic programming ability is



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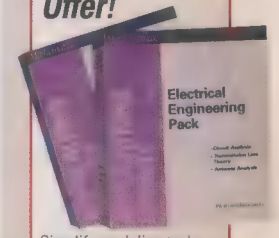
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Circle No. 46

Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Momentum Data Systems, Costa Mesa, CA; 714-557-6889; fax, 714-557-6469				
QEDesign 1000 Circle No. 143	Macintosh: $995 IBM-type PC: $895 Unix workstations: $4200	For digital filter design and analysis	Menu-driven, with complete design capabilities	DSPworks for signal acquisition and analysis; QEDesign 2000 for Unix workstations is an enhancement of QEDesign 1000
National Instruments Corp., Austin, TX; 512-794-0100; fax, 512-794-8411; e-mail, jerry_rodriguez@natinst.com				
HiQ Circle No. 144	Macintosh: $695	Object-based numerical analysis software provides integrated graphical environment for solving real-world problems	Has 600 math functions; publication-quality output; interactive 3-D graphics; scripting language; compiler; set of application-specific Problem Solvers	LabSuite consisting of HiQ and LabView, $2395
Numerical Algorithms Group Inc., Downers Grove, IL; 708-971-2337; fax; 708-971-2706; e-mail, nilles@nag.com				
Axiom Circle No. 145	Unix workstations: $1200	Powerful object-oriented symbolic solver written in its own language; user-extendable with its own compiler creating stand-alone objects	User extensibility and its own language compiler distinguish Axiom from similar products	Part of family of numerical, symbolic, and visual analysis tools
NAG C Library Circle No. 146	Macintosh: N.A. IBM-type PC: $349 Unix workstations: $780 Other: $2664+	Capabilities include BLAS, ODEs, splines, curve-fitting optimization, statistics, and special functions	Object and source code available; performance and accuracy optimized for each computer environment	Part of family of numerical, symbolic, and visual analysis tools
NAG F190 Library Circle No. 147	IBM-type PC: available 1995 Unix workstations: $795+	Numerical package exploits the increased power and functions of Fortran 90	See above	See above
NAG Fortran Library Circle No. 148	Macintosh: $269 IBM-type PC: $269 Unix workstations: $995+ Other: most computers	Comprehensive numerical library includes BLAS, ODEs, PDEs, splines, FFTs, special functions, optimization Eigenvalues and vectors, and statistics	See above	See above
Poly Software International Inc., Salt Lake City, UT; 801-485-0466; fax, 801-485-0480				
PSI-Plot Circle No. 148	IBM-type PC: $299, or $49 upgrade to Version 3.0	Technical plotting and data-processing software	Version 3.0 adds math capabilities, including nine methods for solving ODEs; also new fonts, on-screen rulers, customer-controllable desktop color, new plotting types, and improved zoom/unzoom function	SigmaPlot, Diffeq, Axum
Quantitative Technology Corp., Beaverton, OR; 503-626-3081; fax, 503-641-6012				
Math Advantage Circle No. 149	Macintosh: $1300+ IBM-type PC: $1300+ Unix workstations: $3250+ Other: call vendor	Single- and double-precision subroutine library for science and engineering; algorithms and routines boosted from 604 to 996	Source or object code; C, Fortran or Ada	Most popular member of Numerical Advantage Series
Spec Advantage Circle No. 150	Macintosh: $2600+ IBM-type PC: $2600+ Unix workstations: $1700 Other: call vendor	High-performance library includes numerous special functions such as single- and double-precision floating-point routines	See above	Member of Numerical Advantage Series
Stat Advantage Circle No. 151	As above	High-performance library includes numerous algorithms for statistical analysis	See above	See above

limited. Programmability is a key feature of math software, for without it users are unable to solve any but small problems. Some, certainly, may never want to solve a problem longer than a few equations, but software manufacturers are loathe to give anyone an excuse to not buy their product. It is true, too, that numerous users have found themselves solving larger and larger problems with their math software simply because solving problems got easier.

Consequently, Matlab, Maple, Mathematica, and others equip their users with high-level programming languages, which easily make up in speed of writing for any time it takes to learn them. They are truly one of the greatest offerings the new math programs have to give engineers.

To name names, Mathematica now has MathLink on PCs and Macs. MathLink is a communication standard written by Wolfram Research that allows many different programs to act as a front end to Mathematica. In fact, Microsoft Excel and Matlab are all linked to Mathematica through Mathlink programs, as are Labview and Hypercard. Labview is the virtual instrument program sold by National Instruments Corp., and Hypercard is an object-oriented programming tool now sold by Apple Computer Inc. In effect, just as Mathcad removed its programming limitation, Mathematica removed its interface limitation.

Internet and Netlib

The Internet has become a cornucopia of information. Engineers may post questions, and discuss their math interests, in such newsgroups as sci.math.symbolic and sci.math.general. There is also a lot of public domain software available through the Internet. An excellent introduction to Netlib is obtainable from Frederick Chapman of LeHigh University. He may be reached via e-mail at fc03@LeHigh.Edu. Netlib is mostly a collection of Fortran-based numerical methods. Many of the routines are out of the *Transactions of the ACM.*

Also available through Netlib is Slatec, a library of math routines comparable to NAG or IMSL. Several Netlib mail servers are available all over the world. In the United States, for example, netlib@research.att.com is the server at AT&T Corp., in New Jersey, and netlib@ornl.gov is the server at Oak Ridge National Laboratories in Tennessee. Anyone sending e-mail to one of these servers with the line "send index" will receive an index of the available software.

It is also possible to access the Netlib via FTP (file transfer protocol). Having run FTP, connect to the Internet node research.att.com, login with the username netlib, and give whatever you want as a password. For those who can use TCP/IP Internet, a graphical interface to Netlib is available through X Windows as Xnetlib. Those engineers interested in computer algebra can contact CAIN, the Computer Algebra Information Network, via e-mail at cain@can.nl. CAIN maintains information on computer algebra systems, and is setting up software servers to share information.

Even complete math programs are given away on the Internet. Octave, a high-level language meant for math computation, is available for FTP from ftp.che.utexas.edu. Octave uses a command line interface to handle systems of equations, matrix manipulations, integrals, differential equations, and complex numbers. Octave is a GNU product from the Free Software Foundation.

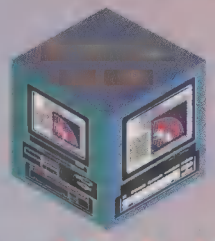
—*A.R.*

Power and capability have become standard advertising claims of just about every math program. Plots, numerical analysis, symbolic analysis, access to a programming language, and a large foundation of mathematical functions have become standard features.

A casual glance suggests that all the programs have more or less the same abilities. Compiling a check list of features may result in a tie between programs, which in almost all cases can easily plot in three dimensions, solve certain integral equations, invert matrices, and perform Fourier transforms.

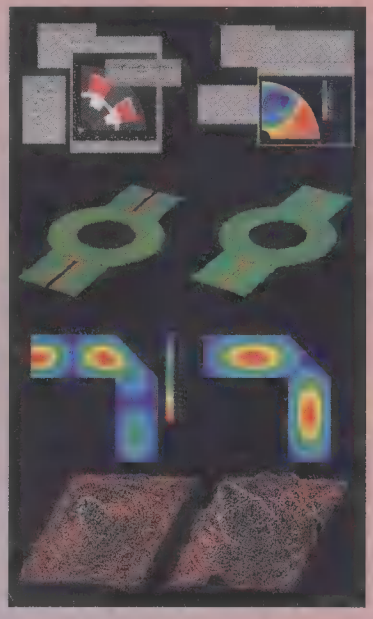
But the real difference is the user interaction—not just the user interface, but how the user works with the program. Thus a key

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Symbolic and numerical math software *(continued)*

Name	Platforms	Package descriptions	Comments	Related packages
Rechenzentrum, Karlsruhe University; Karlsruhe, Germany; (49+721) 608 4034; fax, (49+721) 32550				
Fidisol/Cadsol Circle No. 152	Macintosh: N.A. IBM-type PC: DM 250 Unix workstations: DM 250 Other: DM 250	Solves systems of 2- and 3-D nonlinear partial differential equations on rectangular and body-oriented grids; finite difference method; optimized for vector computers	Source code in Fortran can be modified	Vecfem
Vecfem Circle No. 153	See above	See above, except uses arbitrary-domain finite-element method in place of grids	Interfaces to Patran and I-Deas; source code in Fortran can be modified	Fidisol/Cadsol
Research Systems Inc., Boulder, CO; 303-786-9900; fax, 303-786-9909; e-mail, info@rsinc.com				
IDL Circle No. 154	Macintosh: $1500 IBM-type PC: $1500 Unix workstations: $3000+ Other: $1500	Integrated computing environment for developing custom applications	Math features include built-in numerical recipes, routines, and a statistics library	PV WAVE, MatLab
SAS Institute Inc., Cary, NC; 919-677-8000; fax, 919-677-8224; mary_ann_hansen@mac.sascom				
JMP Software Circle No. 155	Macintosh: $695	Statistical visualization and exploratory data-analysis tool	Has experiment-design capabilities; contour plots for any configuration; tear-off menus for tools, colors, and markers; includes general linear and nonlinear modeling, hierarchical cluster analysis, stepwise regression, cross tabulation, nonparametric correlations, inverse prediction and survival analysis; directly imports data from relational databases	—

question to ask about using one of these math programs is how long it takes the newcomer to get started. A large manual is intimidating, and many engineers want to fire up the program and go to work without reading anything.

As programs become more general and powerful, they also take longer to learn and become more intimidating. To quell those fears, Matlab began years ago by providing Toolboxes, Mathcad followed with Function Packs and Electronic Books, and now Wolfram Research joins in with Application Libraries. Each software manufacturer has a different approach to helping an engineer get started, but all of them want to get him working quickly.

The Matlab toolboxes are tailored to a variety of engineering disciplines: control theory, signal processing, signal identification, and neural networks are just a few. These toolboxes are collections of functions essential to engineers but which they may find too sophisticated and time-consuming to write themselves.

A toolbox may be one or more m-files containing Matlab code in an easily loadable form. An engineer does not have to see what is in an m-file; she only needs to see that Matlab knows many more useful functions once an m-file is loaded. Toolboxes often cost several hundred dollars or more, but are well worth the money.

MathSoft, the producer of Mathcad, sells function packs and electronic books to go along with the Mathcad. These packs and books provide a wide variety of solutions to common problems. Since engineers enjoy examples, these Mathcad additions have been very useful. However, the additions are neither as technical nor as comprehensive as the Matlab toolboxes. In part this is because Mathcad lacks Matlab's programmability. But just as important is the fact that the two markets are different: Matlab aims more at the specialist, while Mathcad attracts the more general user.

HOW-TO TUTORIALS. Mathematica entered the market, in 1988, with the reputation of being the most ambitious and comprehensive program of its time. That comprehensiveness even today has many engineers believing Mathematica is too difficult to learn. Accordingly, Wolfram Research, its producer, decided it would jump-start potential users with application libraries, which are essentially tutorials on how to apply Mathematica to a field.

Wolfram Research has positioned its libraries somewhere in between Mathcad's function packs and Matlab's toolboxes. The libraries include a useful, but not necessarily exhaustive, set of functions oriented toward a specific discipline. The first two to hit the market are in electrical engineering and financial analysis.

The company in addition encourages third parties to develop more complete packages for Mathematica in any discipline. (For the past two years Wolfram Research has held a conference just for third-party developers.) MathTensor, one of the first third-party packages for Mathematica, supplements it with a comprehensive set of tensor manipulation functions.

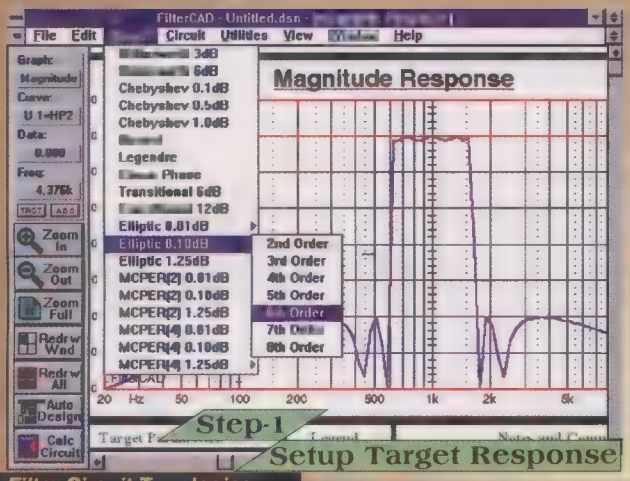
KNOW YOUR NICHE. With all of the emphasis on comprehensive math programs, the old idea of math subroutines may appear to have been lost. Yet Fortran and C libraries are still a successful niche, popular with engineers who choose to write their own programs with the aid of a C or Fortran compiler. After all, libraries from NAG and IMSL undoubtedly contain efficient, fast, and reliable solutions to some very difficult numerical problems.

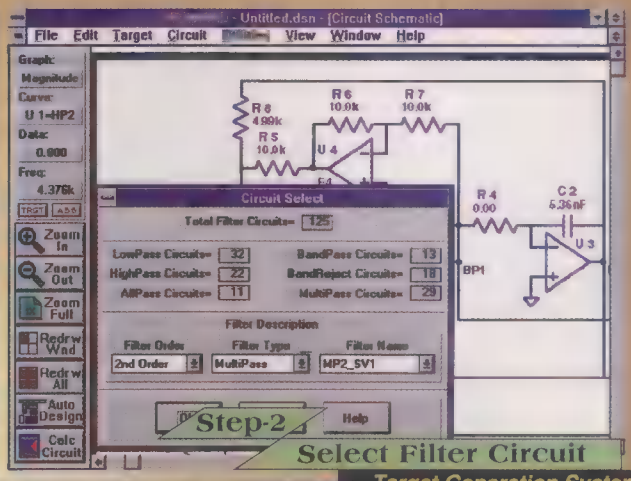
In fact, the code in the NAG and IMSL libraries has proven useful to many people for many years. As well as being robust, these routines have also been optimized for

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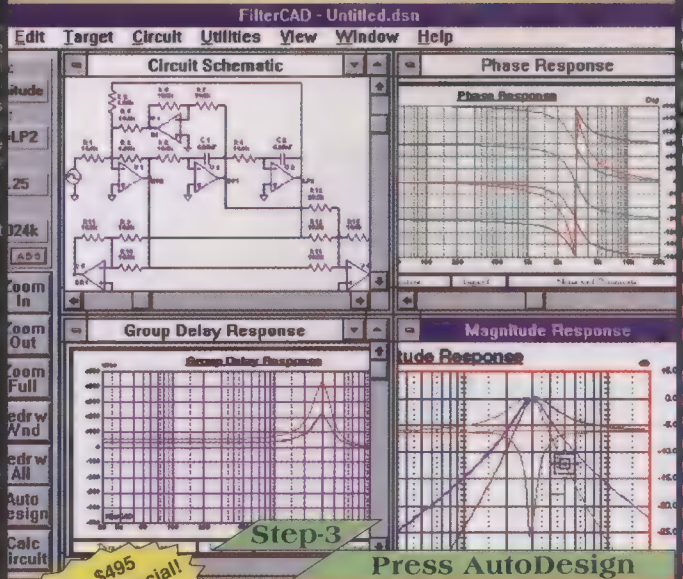
contains a catalog from the user can a circuit circuits for a The and filter thesis for each of these circuits has been and into the enables FilterCAD to the circuit itself based a few choices by the user.

Filter Circuits

- 125 different circuit 1st
- 8th order and more
- User controllable model
- Unlimited cascade
- filters 8th
- RLC ladders to 8th order
- RDC ladders FDNRs to 8th order
- Gyrator for 'L' and 'D'
- 1st-4th order state ads
- Allpass lattice
- Twin-Tee and Bandreject circuits
- Bandpass Bandreject circuits
- Asymmetrical LPN/HPN circuits
- 1st-4th order LP/HP/AP/BP/BR
- Many other 1st and 2nd

System Features

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- Circuit Impedance
- Unlimited
- User controllable resolution
- User controllable scale
- Custom graphs, line widths, colors
- ABS/REL cursor readout
- ASCII data export
- raster and vector
- SPICE net generation



Target Generation System

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Custom Target Controls

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- TF poles and
- Transfer Blocks 8
- TFB Parameters Ao, Fz
- LP1,HP1,AP1,LP2,HP2,AP2,BP1,BR1
- TFB switches
- Automatic to circuit

Standard Target Functions

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- Full transformations LP,HP,AP,BP,BR
- Butterworth 3 dB
- Chebyshev 0.1 dB 0.5 dB 1.0 dB
- family
- Transitional dB 12 dB
- Elliptic 0.01 dB 1.25 dB
- MCPER(2) 0.01 dB
- MCPER(4) 0.01 dB / 0.1 d .25

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Adobe or True Type Fonts.

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Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
The SAS System Circle No. 156 (second of two items)	IBM-type PC: $730 Unix workstations: $730 Other: mainframes and minicomputers, call vendor	For statistical analysis, offers interactive matrix programming language, guided data analysis, spreadsheets, and financial applications	Control of execution, program modularization, and graphics production. Also has features for arithmetic and character expressions, data input and output	—
Scientific & Engineering Tools Inc., Sinking Spring, PA; 610-678-8787; fax, 610-678-8703				
ESPro Circle No. 157	IBM-type PC: $895 Unix workstations: $5000	Custom tool set for application development, data analysis	Most cost-effective for large jobs; has large library of routines	—
Signal Technology Inc., Santa Barbara, CA; 805-899-8300; fax, 805-899-4344				
Data!Power Circle No. 158	Unix workstations: $1900+	Provides math and analytical functionality through a high-level object-oriented symbolic standard IEEE language	Object-oriented 2- and 3-D graphics allows convenient user interaction with data and results; functions accessible through block diagrams, menus, pop-ups, or command browser window	Member of N!Power family for data acquisition, analysis, and visualization; math analysis; and digital signal processing
Soft Warehouse Inc., Honolulu, HI; 808-734-5801; fax, 808-735-1105				
Derive, A Mathematical Assistant Circle No. 159	IBM-type PC: $125	A symbolic math system with programmability and 2- and 3-D plots	Menu-driven, infinite-precision arithmetic, demonstration files, on-line help; Version 3.0 has new math capabilities and plot Window features, improved user-interface; does equation solving, arithmetic, calculus, trigonometry, matrices, more	—
Derive XM Circle No. 160	IBM-type PC: $250	See above	See above, but handles bigger math problems than Derive	XM is the extended-memory version of Derive
Spectrum Signal Processing Inc., Burnaby, BC, Canada; 800-663-8986; 604-421-5422; fax, 604-421-1764; e-mail, tim_marchant@spectrumsignal.bc.ca				
ViPEr Circle No. 161	IBM-type PC: $15 000	Visual programming environment for developing DSP software on an arbitrary array of TMS320C40 DSPs	Windows-based object-oriented DSP programming, graphical representation of signal flow, graphical interactive debugger, waveform generator; includes over 150 DSP math functions; can import code	Member of a family of DSP engineering boards and software for the PC, VME, and SBus environments using DSP chips from TI, Motorola, Analog Devices, and AT&T
Techni-Soft, Livermore, CA; 510-443-7213; fax, 510-743-1145				
SSPACK_PC 3.0 Circle No. 162	Macintosh: $995+ IBM-type PC: $995+ Unix workstations: $2995+	Model-based signal processing package using UD-Kalman filter algorithms for multichannel linear and nonlinear signals and systems	New interactive GUI ported under MatLab Version 4.0+ on all platforms supported; integrates push buttons, windows, pull-down menus, and color graphics; allows complete model simulation, estimation, and identification; has nonlinear iterated extended Kalman filter design option	Only complete model-based signal-processing package with these capabilities under the MatLab environment
SSPACK 3.5 Circle No. 163	Macintosh: N.A. IBM-type PC: N.A. Unix workstations: $4000+ Other: mainframes, $6000+	Stand-alone model-based signal-processing interactive environment for the design, analysis, and display of linear and nonlinear, time-invariant and -varying, single- and multichannel signals	Solves the complete model-based signal-processing problem from simulation to application; upgraded version has pull-down menus, enhanced color graphics, unique integration of buttons, menus, and windows	—

speed. Subroutines in Fortran and C admittedly ask for greater expertise on the part of their user than a general math program does. However, the compiled functions can be linked with the user's own compiler into the user's own program and used transparently.

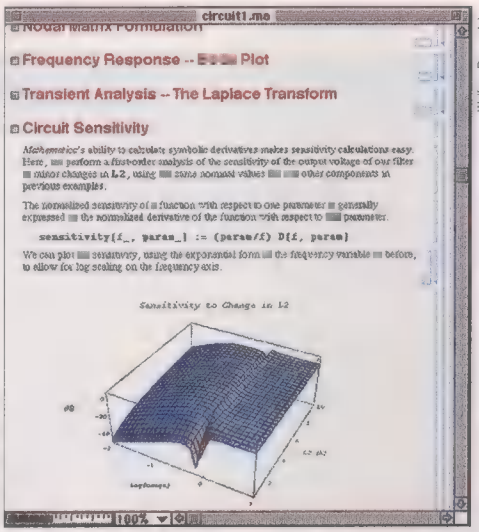
As a rule, general-purpose math programs take up tens of megabytes of disk space and at least as much dynamic memory when running. Consequently, in spite of the speed and storage improvements in personal computers, a compiled solution remains very attractive.

WHEN SPEED IS IMPERATIVE. What weighs most heavily, perhaps, is the problem of speed. A general math program for, say, inverting a matrix can take two to 10 times as much time to run as compiled Fortran code takes. A symbolic analysis program has obviously greater storage and greater housekeeping overhead than a dedicated numerical function does, and so will always be slower. Someone who needs speed and compactness needs a compiled subroutine.

In brief, engineers may use a general-purpose math program to develop and test an algorithm, and then use library routines and compiled code to implement the final analysis program. Thus general-purpose math programs and code libraries are actually symbiotic. The first lets an engineer develop a problem solution in interactive steps and speedily create an algorithm for solving the problem in hand. The compiler and the function library between them supply the fastest and most efficient way to solve the problem on a repeated basis.

This being the case, it is not surprising to find that Matlab's Simulink contains a C code generator designed to convert Simulink solutions into digital signal-processing hardware code. Or that Macsyma contains C and Fortran code generators capable of writing entire programs. Or that Mathematica contains C and Fortran translators that convert lines of the Mathematica language into those lower-level languages. General-math programs can serve as a very efficient platform for developing and debugging algorithms. Then if an engineer implements the algorithm in C or Fortran, he or she has all the test data required to check the results—and often the math program automates a lot of the code translation.

PICKING AND CHOOSING. There is no perfect program here. Even though the feature sets of several of the programs may seem identical on the face of it, engineers will find the



Wolfram Research Inc.

[3]. The Mathematica "notebook" for solving circuit analysis problems contains a combination of text, graphics, function definitions, and plots. Each heading has a collection of information grouped under it, forming a collapsible and expandable cell. A gray box at the left of a line denotes a heading. The gray vertical lines at the right of the window denote individual cells of information. When a cell is collapsed, a rectangular box appears near the vertical line and can grow to show how much information is in the cell.

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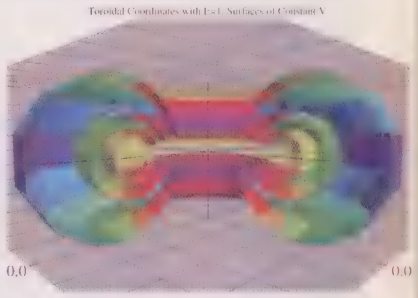
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Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
The Athena Group Inc., Gainesville, FL; 904-371-2567; fax, 904-373-5182; e-mail, support@athena-group.com				
Siglab Circle No. 164	Macintosh: N.A. IBM-type PC: $99 Unix workstations: N.A. Other: Windows, $199	Integrated signal and system analysis package; 2- and 3-D displays; program scripting language	Menu-driven high-level program and analysis environment	Member of Monarch Series of tools for digital signal processing
The MathWorks Inc., Natick, MA; 508-653-1415; fax, 508-653-6284				
Matlab Circle No. 165	Macintosh: $1695 IBM-type PC: $1695 Unix workstations: $3395	Matrix-based numerical analysis package; a comprehensive system for interactive computation, 2- and 3-D visualization, modeling and algorithm development	High-level language has over 500 numeric and graphical functions; includes platform-independent GUI development tools; over 15 application toolboxes available; new Windows version supports dynamic data exchange and notebook suite	Part of the Matlab environment for technical computation and scientific visualization
Matlab Symbolic Math Toolbox Circle No. 166	Macintosh: $595 IBM-type PC: $595 Unix workstations: $1995	An extension of Matlab; an intuitive environment for symbolic computation; integrated with Matlab's numerical processing capabilities	Matlab Symbolic Math Toolbox includes Maple core library and linear algebra package; extended Symbolic Math Toolbox provides access to full Maple functionality, including Maple programming	Member of Matlab environment, which includes Matlab and Matlab Application Toolboxes
TriMetrix Inc., Seattle, WA; 206-527-1801; fax, 206-522-9159				
Axum 3.0 Circle No. 167	IBM-type PC: $495	Publication-quality technical graphics and data analysis	Mouse support, WYSIWYG graph editor, batch processing, programming language manual; import ASCII, Lotus, and dBase files, analyze data and create 2- and 3-D graphs	Axum 4.0 for Windows
Universal Technical Systems Inc., Rockford, IL; 815-963-2220; fax, 815-963-8884				
TK Solver Circle No. 168	Macintosh: $395 IBM-type PC: $299 Unix workstations: $995	Environment for solving problems forward and backward; rule-based system can be used as an algebraic problem-solving tool, a mathematical model builder, or knowledge management system	Now available for Windows	TK is the engine that powers the applications Roark and Young on TK, Heat Transfer on TK, and dynamics and vibration analysis
Vanguard Software Corp., Smithtown, NY; 516-979-6863; fax, 516-979-6829				
DecisionPro Circle No. 169	IBM-type PC: $495	Assists in decision-support analysis using math models; supports decision-tree analysis, Monte Carlo simulation, and other techniques for making decisions in the face of uncertain outcomes	Basic math capabilities include units of measure, complex numbers, matrix calculus, numerical integration and differentiation, root solving, regression, linear optimization, rule-based systems, and full programmability; supports OLE, DDE, and data import and export	DecisionPro is the Windows version of HyperCalc, Vanguard's DOS-based math application, with expanded presentation and analytical capabilities
Visual Solutions Inc., Westford, MA; 508-392-0100; fax, 508-692-3102; e-mail,info@visol.com				
VisSim Circle No. 170	Macintosh: N.A. IBM-type PC: $495+ Unix workstations: $895+ Other: Windows NT, $795+	Nonlinear dynamic simulation supporting 80+ math functions; supports MIMO state space and transfer functions; display functions include interactive, embedded plots, strip charts, plot zooming, and numerical displays and indicators	Programmed through a graphical block-diagram programming language; supports data exchange with Matlab, Maple, Mathmatica, Excel; can be extended through user DLLs; also supports Interactive parameter changes, automatic parameter optimization, and stiff solver	Add-on products handle frequency domain analysis, code generation, neural nets, real-time data acquisition, and discrete-event modeling

Symbolic and numerical math software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Waterloo Maple Software Inc., Waterloo, ON, Canada; 519-747-2373; fax, 519-747-5284; e-mail, mmcinnes@maplesoft.on.ca				
Maple V 3.0 Circle No. 171	Macintosh: $795 IBM-type PC: $795 Unix workstation: $1795 Other: Various, $795+	Handles symbolic algebraic expressions, arbitrary-precision numerical arithmetic, programming, and scientific visualization	Routines can be customized; performs thousands of symbolic and numeric calculations; scientific visualization, programming, and document preparation with standard math notation; offers enhancements in graphics, help facilities, and Maple's worksheet interface; library of 2500+ functions	—
Theorist 2.0 Circle No. 172	Macintosh: $290 IBM-type PC: $290	WYSIWYG symbolic mathematics and graphing for interactive investigation of mathematical equations	No programming languages to learn; generates colorful graphs quickly; enables file exchange between platforms and electronic file transmission without special conversion	Part of the Maple family of math and equation editing software for scientists, educators, mathematicians, researchers
WaveMetrics Inc., Portland, OR; 503-620-3001; fax, 503-620-6754; e-mail, wavemetrics@applelink.apple.com				
Igor Pro 2.0 Circle No. 173	Macintosh: $495	For numerical data analysis, automation, and journal-quality graphing	Very fast, handles large data sets, extendable and programmable	Optional Igor XOP Toolkit adds extensibility via C modules
Wolfram Research Inc., Champaign, IL.; 217-398-0700; fax, 217-398-0747				
Mathematica 2.2 Circle No. 174	Macintosh: $595+ IBM-type PC: $595+ Unix workstations: $1995	Integrated math system for numerical, symbolic, and graphical computation and visualization; offers an interactive calculation tool and a versatile, high-level programming language for fast and accurate solutions to technical problems	Uses MathLink to make seamless connections to C, Fortran, and many commercially available software applications; supports functional, object-oriented, procedural, and rule-based programming; has over 2 000 built-in functions	Newly available Mathematica Electrical Engineer Pack offers special functions, programs, and practical examples for circuit analysis, transmission line theory, antenna analysis, and more; an extensive collection of engineering packages and examples in signal processing, neural networks, and other areas is available free through MathSource, Wolfram Research's electronic resource of Mathematica-related materials

BLAS = basic linear algebraic subprogram
DDE = dynamic data exchange
DLL = data link library
DSP = digital signal processing
FFT = fast Fourier transform
GUI = graphical user-interface
MIMO = multiple input, multiple output
N.A. = not applicable
ODE = ordinary differential equations
OLE = object linking and embedding
PDE = partial differential equations
WYSIWYG = What You See Is What You Get

programs very different. Each individual must know how far she or he can trade ease of use for capability. Nor may anyone assume that linking one program with another gives the best of both worlds, for sometimes the links offer only limited abilities.

On the other hand, engineers should recognize that once they get into the habit of using a math program, they will find additional uses for it. Do not underestimate your ultimate needs—you may surprise yourself.

Derive and Theorist are good examples of the more interactive symbolic math programs. Derive is sold by Soft Warehouse, and at version 3.0 is a mature product for IBM-compatible computers. Theorist is available only for Macintosh computers and is sold by Waterloo Maple Software. Engineers who develop programs for others probably would not like either program, but anyone who needs the easiest in symbolic manipulation would be well-advised to look at them first. Derive and Theorist are wonderful at manipulating expressions, but have only a limited ability to store a set of standard manipulations.

In contrast, engineers in search of the fastest numerical analysis will want to look at Matlab first, because programs built on a symbolic engine will require more memory and be somewhat slower. Others who develop simple solutions for themselves will find the clarity and openness of Mathcad very useful; but as their problems become more complex, they will find pages of Mathcad expressions confusing. For advanced problems, Mathematica and Matlab are easier to use because they can store the details of analysis in a high-level language and in a separate file.

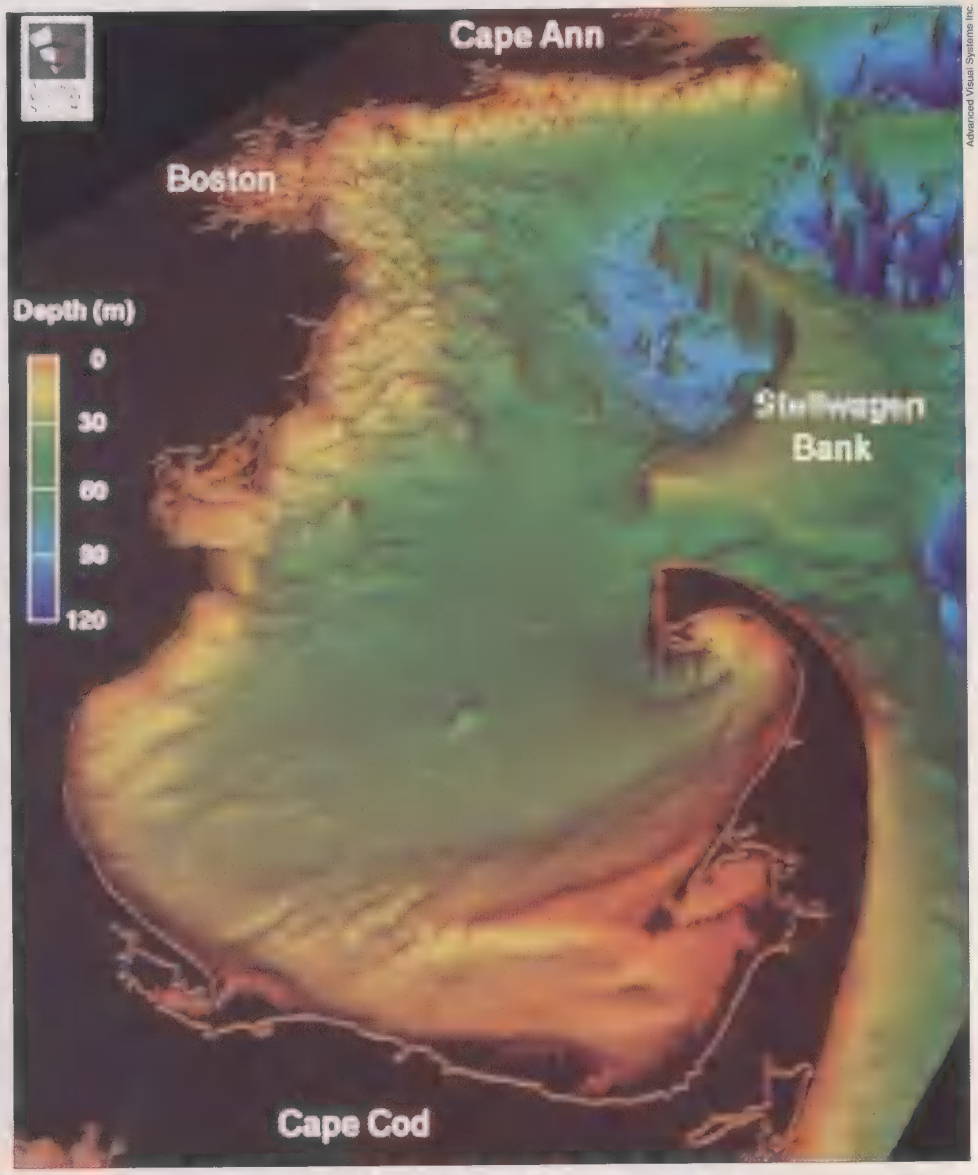
Engineers should not be concerned with the cost or memory requirements of the program they buy. The time spent learning the program, and the time saved in solving problems, will make the cost of any of these programs negligible.

The real issue is which program fits your needs best. Go buy that program, and enjoy it. ◆

ABOUT THE AUTHOR. Alfred Riddle has run Macallan Consulting, of Milpitas, Calif., since 1990. He favors mathematical software for solving most circuit design problems, but reverts to C and Fortran when he has to. In addition, he spends a lot of time burning solder and back-modeling circuit performance. His favorite areas of research are noise analysis, electromagnetics, and filter design. He is secretary of the Santa Clara Valley Chapter of the Microwave Theory and Techniques Society.

Visualization: the look of reality

The art (and science) of making visible whatever is hard or impossible to see in the physical world has led to a multibillion-dollar industry



[1] The U.S. Geological Survey used the AVS scientific visualization package to simulate effluent flow and dispersion from a new sewage treatment plant being proposed for Boston Harbor. This image shows the topography of the sea floor in the area.

The need to understand behavior, be it of objects, systems, or organisms, bred the need to simulate it visually, which has been in turn the prime catalyst in the use of computer graphics. A 1987 National Science Foundation report helped give the term "visualization" a place in the computing lexicon, and by now the field has generated a multibillion-dollar industry in software, hardware, and related equipment. In short, visualization is growing up, having moved from research to desktop in a wide variety of environments.

At bottom, visualization is the process of making visible what is hard or impossible to see in the physical world. It therefore embraces the display of volumetric data and representations of fields and mathematical phenomena, plus distributed visual processing, the use of animation (to add the dimensions of time and motion to a subject), and the mating of visualization capabilities with software for such tasks as finite-element analysis. All this goes on in a computing environment that ranges from small personal computers all the way to special-purpose visualization and rendering systems. And such areas as virtual reality promise users even deeper immersion in the interactive environments for exploring behavior.

Interest in scientific visualization at first focused on large-scale, data-intensive applications, like depicting medical images and enhancing satellite data. But today, scientific visualization techniques are being employed in ways that would have been all but unimaginable a decade ago—witness environmental modeling, structural analysis, and golf.

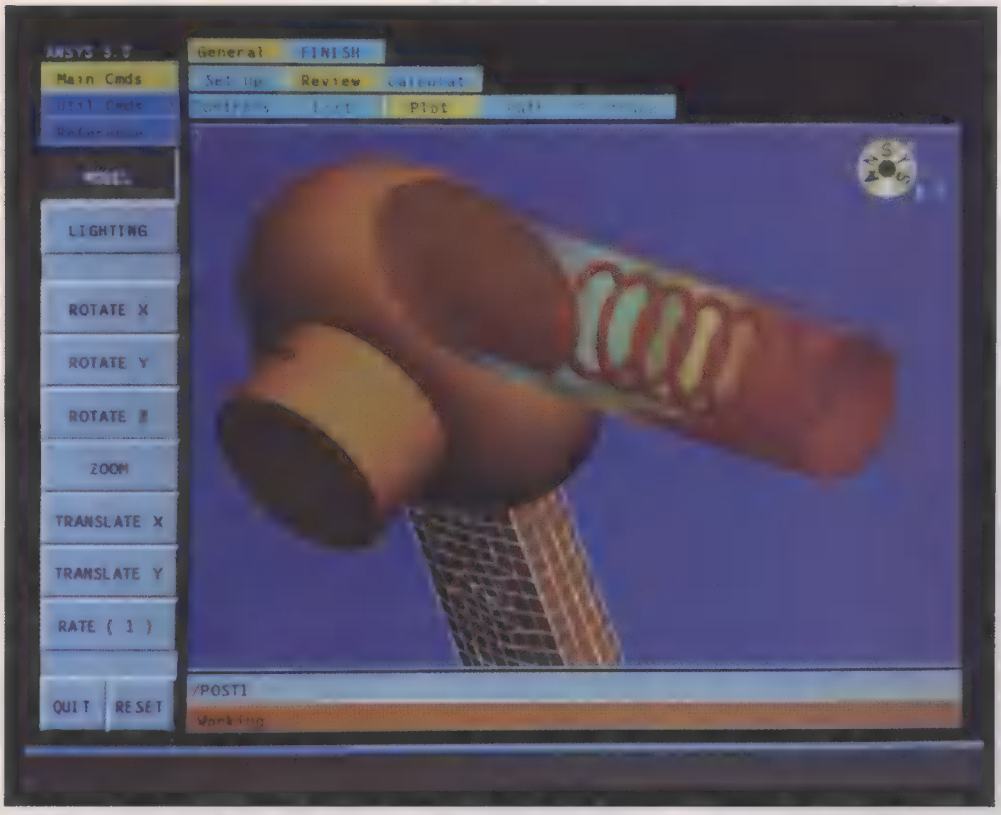
For example, in the cleanup of Boston Harbor, the U.S. Geological Survey wanted to show a general audience how effluents would flow and disperse from a proposed sewage treatment facility. The agency employed the Application Visualization System (AVS) from Advanced Visual Systems Inc., Waltham, Mass., to produce an animated videotape on the subject. The tape demonstrated that the plant would vastly reduce the amounts of sewage and sludge impinging on sensitive areas like

Richard S. Gallagher Ansys Inc.

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the feeding grounds of whales and the beaches of Cape Cod.

Historically, results from computer-aided structural analysis were presented as "contour plots"—color-coded displays of the surfaces of a structure [Fig. 2]. Today, software packages such as Ansys Inc.'s Ansys utilize isosurfaces, translucency, and volume slicing (of which more later) to display the full three-dimensional nature of structural behavior. Other third-party applications software specialize in the 3-D exploration of structural behavior in real time, including CardinalVision-FEA from CardinalVision Inc., Wilsonville, Ore., and the Focus package from Visual Kinematics Inc., Mountain View, Calif.



Ansys Inc.

[2] Translucency is the name of a visualization technique that lets the user see inside a solid, so as to observe the behavior of an internal component of a three-dimensional object.

As for golf, the NBC television network was planning to cover a golf tournament and worked with William Lorensen and Boris Yamrom of General Electric Co.'s Corporate R&D Center, Schenectady, N.Y. The pair used a mathematical model to visualize the 18th hole green, the trajectory of balls as they approached the hole, and the difficulty of subsequent putts. Television viewers gained a much greater appreciation of the competition.

This trend toward new applications for scientific visualization technology is a sure sign that the field is growing. Today, computer graphics helps to solve many engineering and scientific problems in many fields, among them computational fluid dynamics, molecular modeling, oil and gas exploration, medical imaging, climate simulation, and even the physical modeling of mathematical equations.

Two of the biggest challenges in all of this are conveying information and conveying it quickly. Visualization algorithms developed since the late '80s have made it possible to compute and display imagery that reveals the changing state of one or more internal variables over time and space. The complexity of this visual data bears directly on how fast imagery may be displayed, or how large a dataset may be processed interactively. The ability to visualize real-world behavior in real-world time—or faster—remains a "holy grail."

Real-time visualization—the live, immediate ability to display and interact with visual data—exists today for those fortunate enough to have powerful graphics hardware and/or limited datasets. The obstacles to putting it in the hands of a majority of computer users are related to technology, to both hardware and software, or to cost. But once a user can interact with a model and witness immediately the impact of something he or she has done, that person is hooked. Current research is aimed at clearing the hurdles to truly interactive, real-time visualization.

UNDERSTANDING IN DEPTH. Perhaps the most basic area of visualization research involves developing the algorithms and techniques needed to illumine a 3-D state of behavior. The desire here is to know what is going on inside a model, and to represent that behavior graphically on a computer screen. Such capabilities are especially crucial for applications in the physical sciences and medicine. In fact, one of the earliest applications for volume visualization aimed at allowing a doctor to observe the condition of an organ without cutting into it. This noninvasive exploration of human organs depended on cross-sectional scans obtained by computerized axial tomography.

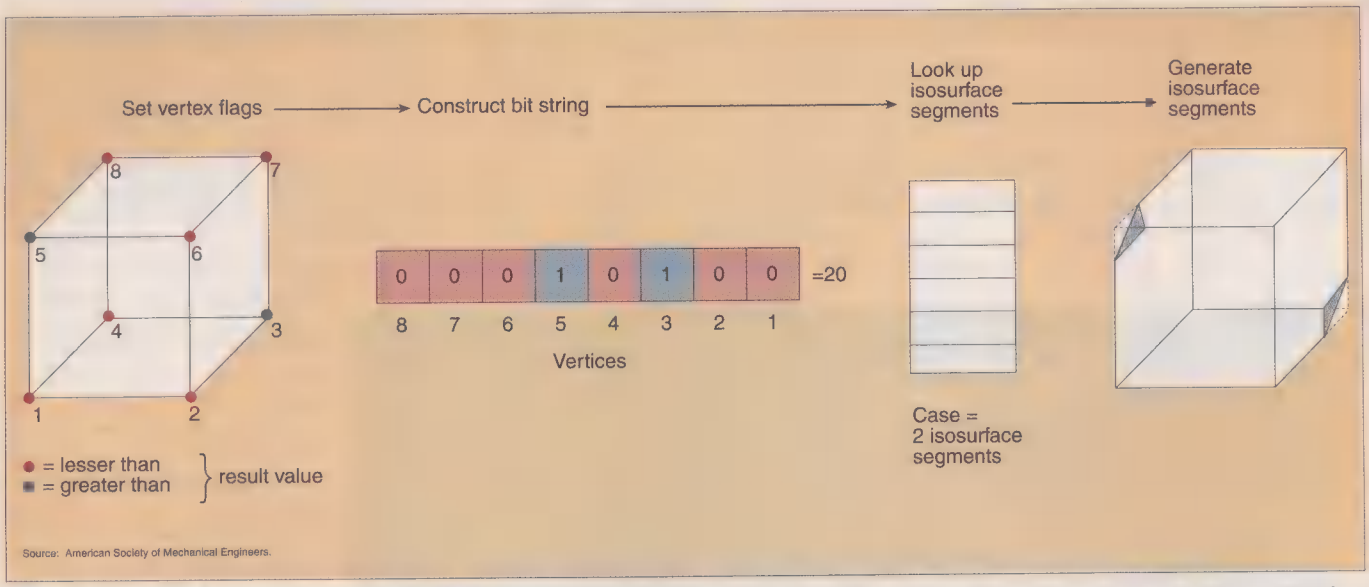
Early techniques for displaying the interior of a field included making it translucent and slicing through it to obtain planes on which color-coded scalar values could be displayed. By comparing the contours on the planes sliced through the model, the user could assess what was happening inside an organ or component. And making an exterior surface translucent exposed components usually hidden from view.

Later research focused on the generation of isosurfaces, which are surfaces of constant scalar value within a 3-D field. Isosurfaces are the 3-D analogy to color-coded surface displays. They frequently provide a very clear view of the overall state of a data field within a solid.

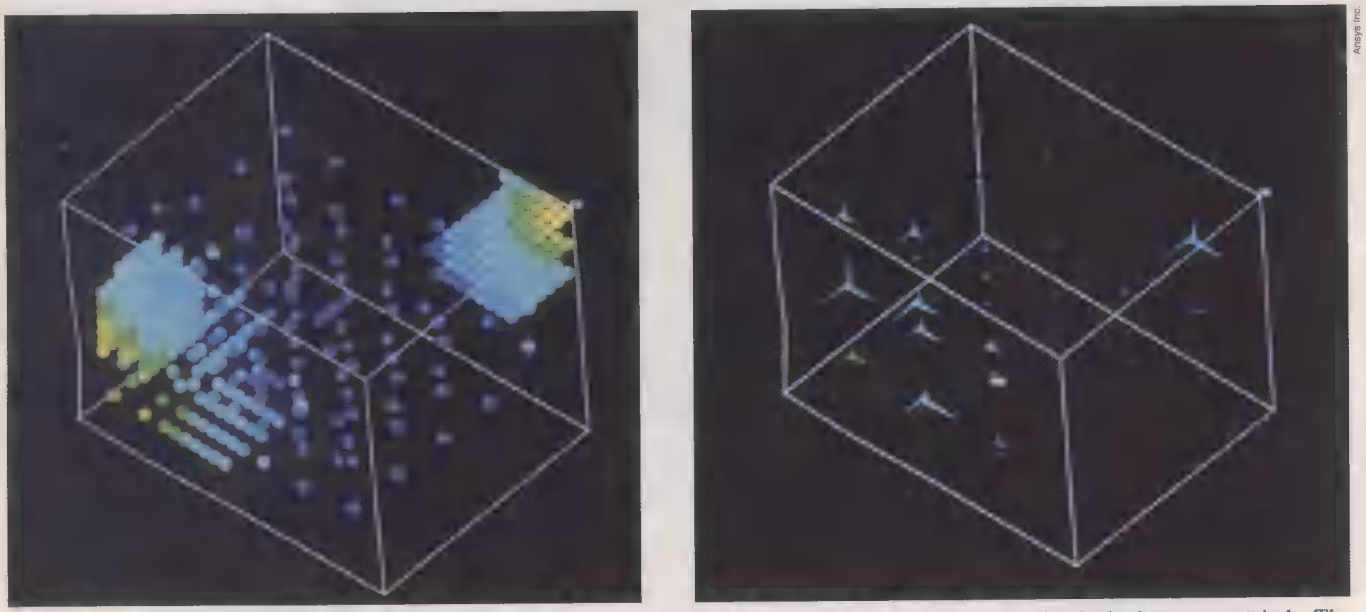
One of the major technical breakthroughs in isosurface visualization was the Marching Cubes algorithm, which was developed by William Lorensen and Harvey Cline and patented by General Electric in 1987. This approach replaced earlier heuristic tactics with a simple, algorithmic method for determining the scalar data values of the isosurfaces within a volume field.

The Marching Cubes algorithm operates upon a field of voxels—a regular spatial array of 3-D cubes [Fig. 3]. These voxels are the volume equivalent of pixels, the dots that make up a computer graphics screen image. The algorithm examines the corner values of each voxel to see if it might contain an isosurface, discarding it if the values are all above or all below the isosurface's value. If an isosurface exists, the pattern of corner values above and below this threshold is used to determine the location of polygons making up the isosurface region.

More recently, a volume has been visualized by relying on varying levels of color or opacity to indicate how data changes within the 3-D field. Techniques here in-



[3] The Marching Cubes approach determines whether a constant-value surface passes through a volume element, or voxel. Each vertex of a unit volume cube is examined to see if its result value exceeds or falls short of the surface threshold. These patterns then determine where to compute the resulting isosurface segments.



[4] Gradient displays, which show the rate of change of a behavior in a field, can be depicted as a particle cloud of spheres or as triads. The spheres are displayed at densities corresponding to their vectors in Cartesian coordinate space [left]. The triads are positioned at element centroids and scaled according to vector values and their directions [right].

clude splatting and ray casting. In splatting, individual voxels are sorted from back to front, and contributions from every voxel's projection to the image plane are composited together. As for ray casting, it is the projection of rays from the image pixel locations through the volume; rays accumulate color and opacity values until each becomes opaque or exits the volume.

As memory becomes still less expensive and hence more plentiful, such volume representation may well become an attractive alternative to traditional surface-based approaches to computer graphics. A group headed by Arie Kaufman of the State University of New York (SUNY) at Stony Brook is researching the area of volume graphics, in which ■ discrete volume space is the means of representing geometry and visualization.

While raster graphics uses the pixel as its primary building block, volume graphics uses the voxel as its basic unit. The concept is predicated on the need to allocate and manipulate large amounts of memory in order to speed up performance. In volume graphics, complex geometric modeling operations can be reduced to operations on groups of voxels. It turns out that the speed of generating an image from ■ voxel field is much less dependent on factors such as image complexity and orientation. That fact alone gives the technique potential for achieving real-time volume visualization in future generations of hardware.

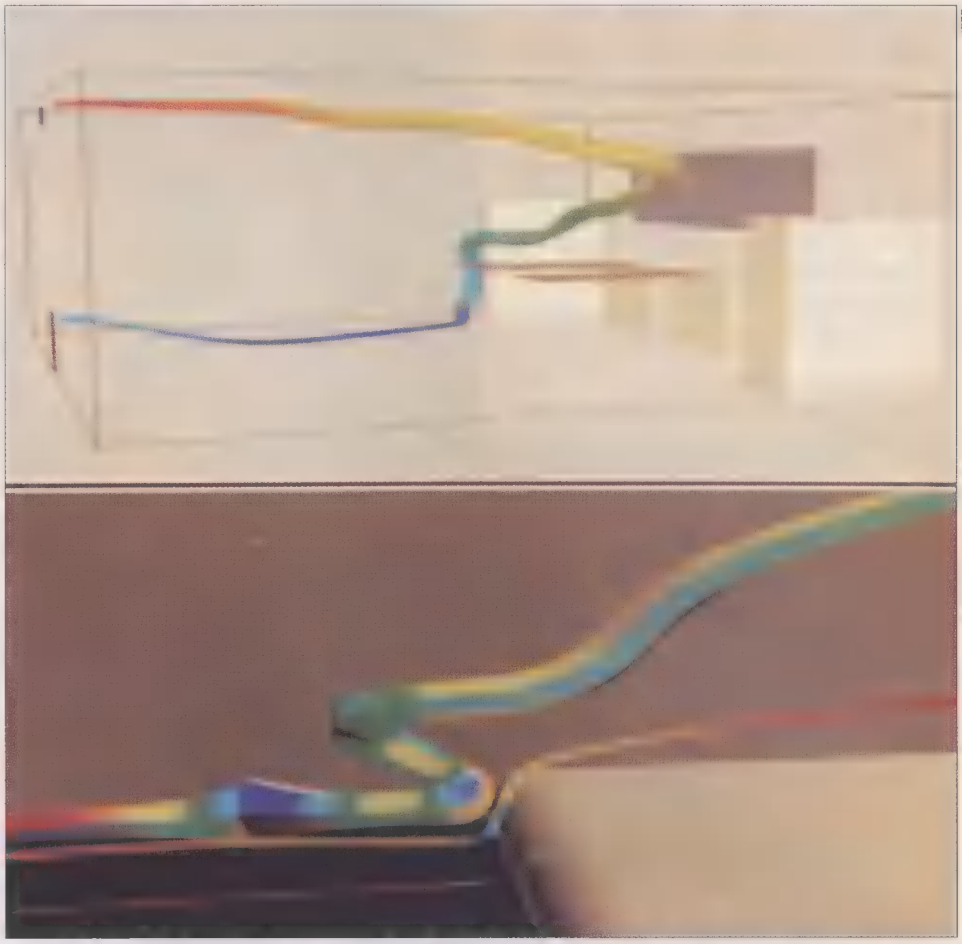
MULTIVARIATE STATES. Lately, one of the larger issues in visualization has been how to display multivariate states of behavior in a comprehensible manner. Data such as vector and tensor fields represent numerous variables at ■ single point in space. It has been a unique challenge to depict this information graphically without cluttering the screen, or overloading the user's perceptual apparaturs.

Early multivariate display techniques included glyphs, which are symbols whose size, shape, and dimensions stand for mul-

tiple indices of information at a point. Glyphs have been coupled with distributions of geometrical shapes whose spatial relationships implied concentrations within a field variable. The Anasys program, for instance, depicts the gradient or rate of change of a scalar variable by means of a cloud of spheres, which are color-coded by their scalar value and displayed at densities corresponding to their gradient [Fig. 4]. Another technique within the same program supplies the same information through triad glyphs positioned at element centroids. The legs of the triads are scaled according to vector values and their directions.

More recent work in the area has sought to display multiple variables as attributes of a path within a field. The stream polygon technique, originally developed at General Electric, permits the visualization or mapping of 3-D vector fields. Stream polygons show scalar and vector quantities in the context of the underlying geometry. Whereas scalar data could be represented by a single value at each computational point, often denoted as color varying over a range, vector data had to be represented by three or more values per computational point. But the use of glyphs or streamlines of paths through the vector field failed to convey a sense of the local deformations that exist within a vector field. Neither rigid body motion (local translation and rotation) nor strain (normal strain and shear/angular deformation) was made evident.

To represent all of the desired information within a vector field, the researchers at GE applied a regular *n*-sided stream "polygon" oriented normal to the local vector. A strip of polygons positioned between and along two streamlines could portray rotation through a technique known as stream ribbon. Strain could be accounted for by rotating and deforming the polygon. Sweeping the stream polygon along the streamline creates a stream tube [Fig. 5]. Shading the stream tube and varying its radius makes it possible to visualize translation, vector magnitude, and scalar functions. Additionally, the user can position the stream polygon interactively to view local strain at any de-



[5] A stream tube depicting a current of air is colored according to air pressure and permits the user to visualize air flow in a room [top]. A streamline, a stream ribbon, and a stream tube have one, two, and three dimensions [above].



[6] The hyperstreamline technique can be used to represent a stress tensor. This image shows four stages of a minor tube in an elastic stress tensor field.

sired point along the streamline.

Subsequent research has gone beyond these efforts to observe still higher dimensions of data. The hyperstreamline, developed by Thierry Delmarcelle and Lambertus Hesselink, both of Stanford University in California, is a visualization technique for tensor fields, representing multiple vector values at each point in space [Fig. 6]. A complicating factor here is that the mind is unaccustomed to forming images of tensor fields.

A tensor field, such as a state of strain or shear stress in a solid, is most simply and naturally represented as a set of three eigenvectors. A hyperstreamline is formed by taking a geometric primitive and sweeping it along one eigenvector field in the transverse plane, under the combined action of the other two orthogonal eigenvector fields. The hyperstreamline is the surface obtained by linking the stretched primitives at various points along the trajectory. It is color coded by means of a user-defined function of the three eigenvalues, generally the amplitude of the longitudinal eigenvalue. A cross section is used to encode the two remaining transverse eigenvectors. The upshot is the continuous representation of tensor data along a trajectory.

The next logical phase in in reseahc into both vector and tensor field mapping is to use polygonal tiling to create stream surfaces and hyperstream surfaces, which are more nearly complete representations of vector and tensor field information. Another trend in visualization is to deemphasize the representation of global data in favor of highlighting those portions of interest to the user.

BRINGING DATA TO LIFE. Two distinct issues exist in moving visualization capabilities beyond the generation of merely visual images, namely, adding the dimensions of time and motion, and providing a basis for interactive manipulation of the data. The first often bears upon traditional computer animation techniques, while the second involves both software techniques and hardware performance.

Animation has been embraced as a visualization tool because it simulates motion or communicates the passage of time, which can reveal trends not readily apparent from still images. Included here are the video transfer of imagery and the digital representation of multimedia (audio as well as video) as part of a database.

The principle behind animation is simple: capture imagery as it changes over time and then play it back rapidly enough for a human being to perceive motion. Putting this into practice has often involved expensive special-purpose hardware, but today cost-effective techniques for animation capture are on the rise. With newer image-compression techniques, sequences may be captured and played back as digital data, with no additional hardware. At the same time, inexpensive video output capabilities on many systems allow the resulting "movies" to be captured on inexpensive home video equipment.

Moreover, as the digital medium catches on for audio, video, and animation, computing networks and databases are becoming friendlier to multimedia information. Such information can already be sent as part of electronic mail, document annotation, or application software. Its digital representation of all this is quickly becoming another standard form of data. Already the increase in audio/video information is expanding use of high-density, interactive media, such as CD-ROM, for storing and distributing the animated data.

Interacting with visualization data in real time brings us a step beyond the image capture and playback of animation. Hardware and software must work together to redraw imagery as quickly as 30 times per second while a user rotates, operates on, or modifies the data. A shift is evident from static, individual images to interactive operations on a field—such as moving a slicing plane through a 3-D solid to see its interior, or guiding a probe, which changes in shape and size, to show a state of behavior at a certain point.

Performance alone has helped bring interactivity to at least the higher end of visualization. In just the past five years, peak graphics performance has improved by nearly an order of magnitude. Today, for example, high-end platforms from 3-D workstation vendor Silicon Graphics Inc., Mountain View, Calif., can display more than 1.5 million shaded polygons per second, while improved performance in general has brought at least some level of 3-D interactive graphics to the low end of workstation-class machines. Even the personal computer arena holds promise for personal 3-D visualization in the near



Photos: IEEE



[7] In this surgical application of enhanced reality, magnetic-resonance imaging data from a patient's head and brain [left] is integrated with live video footage of actual surgery to enhanced the image seen by the surgeon [below].

future, following the recent announcement by Microsoft Corp., Redmond, Wash., of its intention to support OpenGL, a popular 3-D graphics language, under its Windows NT operating system.

The falling cost of memory has had aaddiontal impact on interactive visualization software. In-core storage of larger models becomes possible, as does broader use of memory-intensive techniques such as Z-buffering in software. In this approach, imagery is represented as dots, or pixels, on the screen, and their depths projected in screen space.

"Individual pixels are becoming more important as ■ means for boosting hardware performance," explained Gordon Ferguson, president of Visual Kinematics. "As memory gets cheaper and as CPU [central processor unit] times get faster, I think we'll see greater use of the ability to store data at ■ pixel. You can pile and store CPU time behind each pixel."

The intersection of trends toward interactivity and video multimedia is engendering entirely new applications for visualization, as well. GE's Lorensen has been working on a visualization technique he refers to as "enhanced reality," which combines live video with computer-generated 3-D images.

In surgery, for example, a surgeon can look from the incised area of the body to ■ monitor showing the same view enhanced with ■ computer image [Fig. 7]. The surgeon may use the reference image for a variety of purposes, such as locating the position of ■ tumor or a major blood vessel. Computer-rendered models have been used in surgical planning for ■ number of years, but the use of visualization imagery during live surgery is a true innovation.

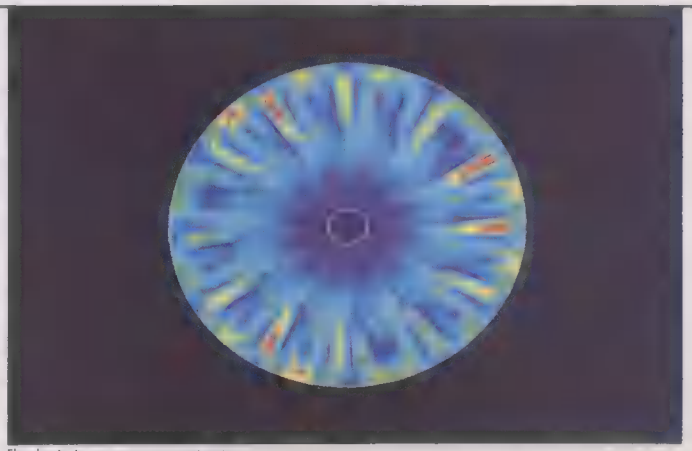
Lorensen points out that while enhanced reality was developed for surgical applications, it is being used for other visualization purposes, such as jet engine maintenance. Maintenance workers can immediately flag ■ problem by comparing the inside of an engine with a computer-aided design (CAD) model. Similarly, the live video that is shot during the photographic inspections in the nuclear power industry is fused with computer models as an additional inspection safeguard. This cross-fertilization of applications continues to be an important trend.

RIDING THE SUPER HIGHWAY. The progress being made on real-time visualization for the individual workstation is also linking it up with the evolution of computing networks. Can several widely scattered users together steer a visualization being run on a remote computer?

A pioneering effort here was an experiment conducted by Robert Haber, of the University of Illinois, at the 1989 Siggraph Conference sponsored by the Association for Computing Machinery, New York City. During this live demonstration, users at a workstation in Boston interactively controlled a visualization session running on ■ Cray-2S supercomputer and visualization server system at the National Center for Supercomputing Applications (NCSA) in Champaign, Ill. The results were displayed as video imagery in Boston.

As Haber is quick to point out nowadays, that particular demonstration used ■ video signal bounced off an AT&T Telstar 302 satellite. Data traveled from the Boston workstation to the supercomputer over 9600-bit-per-second telephone lines. The demonstration therefore did not involve interactive steering via network visualization per se. "There were no transcontinental links [the so-called information highways] to do it digitally then," Haber explained. "Today, we have ■ national testbed linking universities nationwide with the necessary bandwidths."

Once the networks are in place, users could begin visualizing across networks if they have the appropriate tools. The National Supercomputer Centers are already available for remote access. As more networks come on line, users will be looking for means by which they can steer ■ visual-



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Status of scientific visualization in 1994

Developmental area	Trends
Applications	• Cross-fertilization of applications • Medical imaging • Engineering analysis • Molecular modeling • Oil and gas exploration • Climate modeling • Environmental simulation ▪ Growth in vertical applications
Interactivity	▪ Movements toward real-world imagery • Tracking and steering of analysis problems ▪ Development of 3-D oriented input devices ▪ Immersive environments such as virtual reality
Animation, video/audio, multimedia	• Increased usage of image compression techniques • Growth for real-time animation ▪ Increased digital representation of multimedia ▪ Integration of live video footage and computer-generated imagery
Networks	• Development of information highways ▪ Digital transfer of visualization data ▪ Remote visualization • Interactive steering
Visualization techniques (algorithms)	• Movement from scalar to multivariate display • Volume visualization ▪ Vector field mapping • Tensor field mapping ▪ Data reduction vs. global rendering of data
Hardware	• Increasing memory and CPU speeds • Peak 3-D graphics performance > 1.5 million shaded polygons ▪ Parallel and massively parallel hardware, software
Software	• Modular software architectures • Unification of graphics standards ▪ Volume graphics (voxels)

ization session across a distributed network. That's precisely the focus of Haber's latest research project, the Visualization Application Steering Environment (VASE).

The VASE system is similar to a debugger. It provides tools for developing remote visualization functions for applications distributed across a network. VASE is actually ▪ structure with which a user can reach into a visualization code and interactively steer the process while the code is running. For example, VASE could enable its users to interrupt and control a shape-optimization run. Other commercial visualization systems, such as AVS and Silicon Graphics' SGI Explorer package, can also make distributed visualization easier at the level of independent computing processes.

Events since then, at subsequent Siggraph and supercomputing conferences, have confirmed the promise of NCSA's 1989 demonstration. In the summer of 1992, in Chicago, some 35 scientific projects were connected to the Internet from McCormick Place in Siggraph '92's Showcase Exhibit. Supercomputers and remote instrumentation were truly interactively steered over the 45-Mb/s net throughout the United States.

Introduced as part of this forum was the CAVE Virtual Reality Theater. The surround-screen projection-based virtual-reality system was developed by ▪ team led by Tom DeFanti of the University of Illinois' Electronic Visualization Laboratory (EVL) in Chicago [*Spectrum*, October 1993, pp. 30–33].

This exhibit attracted hordes of conference attendees, and by the fall of 1993, the CAVE (an acronym for Cave Automatic Virtual Environment) had been connected directly to a Cray CM-5 massively parallel supercomputer so that it could visualize Einstein's equations at Supercomputing '93. Projects of this nature not only prove that the network is a medium for visualization software, but are now also starting to marry it with immersive interactive environments such as virtual reality.

Furthermore, network advances are starting to have an effect far beyond the individual user. So-called collaborative visualization environments combine interactive shared workspaces with two-way audio and video interactions among participants, and eventually might enable global communities of people to interact with shared data. The same 1992 Siggraph showcase explored applications ranging from remote collaboration during surgery to teleconferencing with "personable computers" having animated facial expressions and synthetic speech. Recently, the National Science Foundation's CoVis project helped to set up ▪ distributed multimedia learning environment in high schools, so that students could jointly explore areas like forecasting the weather.

GROWING STANDARDS. The burgeoning research into techniques and algorithms of scientific visualization is tending toward more modular software architectures and the unification of graphics standards in software. At first, creating applications in visualization required the services of ▪ software developer. Today, many commercial visualization packages employ modular, reusable software components that end-users can modify. For example, AVS and SGI Explorer use a functional approach to assemble capabilities (like processing input data and user interactions) visually on the screen, much like connecting elements of ▪ flow chart.

In addition, there is a rising level of standardization in the languages driving interactive graphics and user interfaces. Consequently, commercial developers of multiplatform software are being encouraged to produce applications architecturally better suited to real-time visualization on today's hardware.

A decade ago, most vendors of graphics display hardware provided their own unique language to create imagery—some applications had to support up to 40 different graphics "drivers." More recent 3-D graphics languages such as OpenGL and PeXlib (an X-Windows extension for 3-D graphics) can provide the means for interactive visualizing across compatible networks. Furthermore, they can work together with window-based graphical user-interfaces (GUIs) on many current hardware platforms.

Still other packages, such as VisTools from Visual Kinematics, supply a higher-level software environment with display functions that can be rapidly implemented around an existing geometric database. At all levels, configurability and software productivity now affect the grade visualization capabilities available to the end user. What's more, trends toward multiprocess, multiwindow GUI environments indicate they will become available in growing numbers as ▪ network resource.

ONWARD TO REAL TIME. For all that, scientific visualization is still ▪ very young field, though it has advanced rapidly in ▪ relatively short time. The popularity of the techniques will as ever be proportional to their practical benefits, and those, in turn, will be related not only to improved hardware and display techniques, but also to advances in algorithms.

"We can't look to hardware for all of our speedups," Lorensen explained. "With hardware, we're looking at improvements by ▪ factor of two every year. But for or-



[9] From GE Corporate R&D comes a noninvasive way of assessing blood flow in the brain. An MRI artery receives a simulated injection of spherical markers, coded blue for fast, red for slow. [Source: H. E. Cline, W. E. Lorensen, and W. J. Schroeder, "3D phase contrast of MRI of cerebral blood flow and surface anatomy," Journal of Computer-Assisted Tomography, *Vol. 17, no. 2, 1993, pp. 173–77.].*

ders of magnitude, we will continue to look to algorithms."

Gordon Ferguson of Visual Kinematics also recognizes the importance of algorithms to real-time visualization. "I think we are going to see more integration of algorithms with traditional interfaces. Algorithms will blur the lines between visualization software and graphics hardware," he said.

All the same, hardware improvements do facilitate new visualization technologies. Ever faster computing and display capabilities at a given price point put 3-D visualization in the hands of many more users, and raise the levels of complexity possible in both the data being visualized and the algorithms themselves. Moreover, display techniques continue to cross over into hardware, boosting image quality and performance. Vendors like Silicon Graphics have hardware that can simulate translucency and texture mapping as surface attributes.

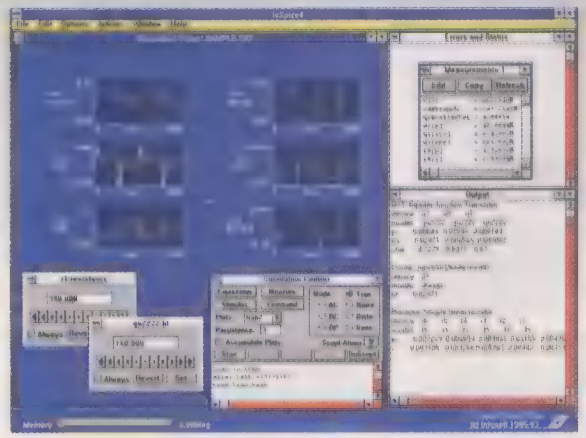
In light of the current trends in the field—memory and CPU advances, media for video and animation, the laying of broader-bandwidth information highways, ever improving visualization techniques, and emphasis on volume graphics—the quest to put real-time visualization capabilities in the hands of most scientific computing users will probably end in triumph within another decade. ◆

ABOUT THE AUTHOR. Richard S. Gallagher is head of computer graphics and user interfaces for Ansys Inc. in Houston, Pa., developers of the Ansys package for engineering analysis. He has been involved in numerous research and commercial projects for the display of numerical analysis behavior since the late 1970s, and is editor of Computer Visualization *(Solomon Press/CRC, 1994). Gallagher is a member of the American Society of Mechanical Engineers and the IEEE Visualization Conference program committee.*

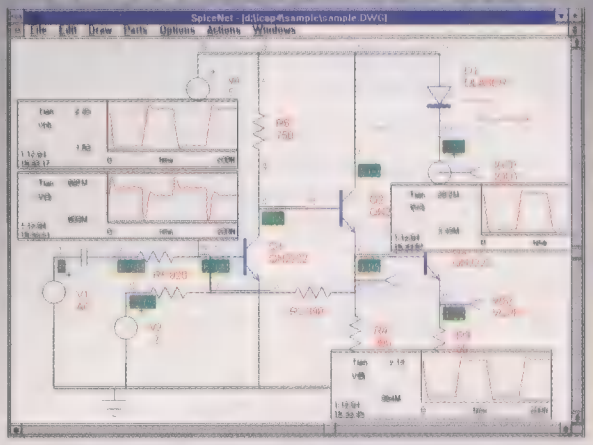
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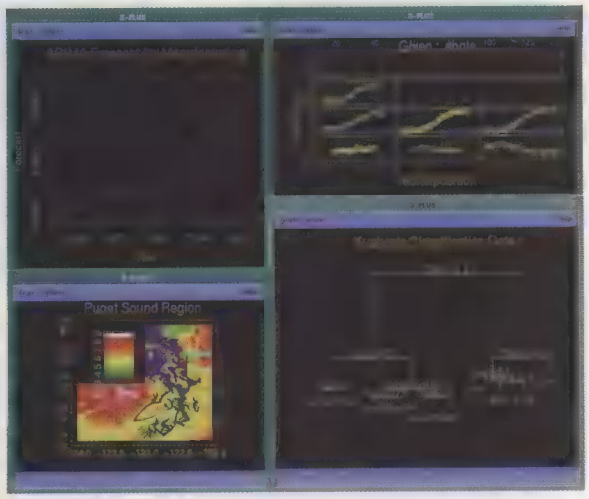
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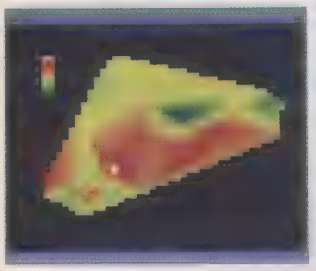
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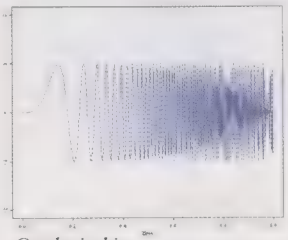
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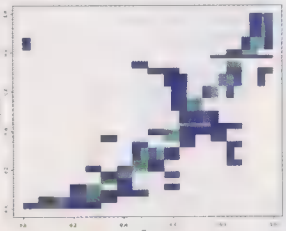
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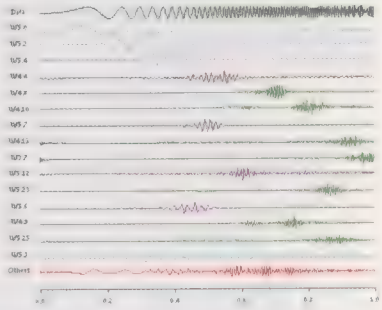
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Active data analysis: advanced software for the '90s

3-D rendering, dynamic exploration, and friendlier environments are among the newest trends in this burgeoning field

More often than not these days, sales brochures from software vendors state that their data analysis products do visualization. Anything from computer-aided design to molecular modeling seems to warrant the description. So the curious reader is left wondering what visualization really means, how the features of the different products compare, where the technology is going, and how much need be spent on a visual data analysis package. What in fact is the difference between a US $100 package and one that costs $10 000 if either may claim to let the user "see" data and analyses graphically instead of, or as well as, numerically?

The first programs for visual data analysis (VDA) were the preserve of an elite group of engineers and scientists dealing with the toughest problems, such as the moon landing. The programs became generally available only about a decade ago and cost hundreds of thousands of dollars. They had limited functionality and required state-of-the-art workstations costing more than $100 000. In contrast, many of the latest VDA programs cost less than $1000, run on PCs, and have much greater analytic powers yielding far more insight into the data than did the leaders of only five years back.

The fact that most improvements in scientific and technical software are incremental does not point to any lack of creativity in its developers: as VDA software demonstrates, some of the most spectacular and unexpected advances cap an accumulation of many small improvements. Nor are the uses and benefits of VDA software obvious at first. The uses later found for VDA may count for as much as those for which a particular program was originally designed.

TONS OF DATA. Today's science and R&D generate tons of data in myriad formats that can no longer be analyzed by conventional techniques. Who can make heads or tails of reams of statistics describing a process or problem? What's needed are tools to reduce the tens, hundreds, or even thousands of megabytes of data into a format that can be comfortably processed by the human brain. That is the reason why more and more scientists and engineers are adopting VDA tools.

Today's visualization programs offer a wealth, perhaps even a superfluity of options. Not so many years ago, their primary technique was the graphical representation of data; little importance was given to data analysis. In a similar vein, numeric analysis software lacked interactive graphics and graphical user-interfaces (GUIs). Now most numeric analysis programs have GUIs and graphics, and many visualization products have added strong analytical capabilities, blurring the distinctions between them and presenting buyers with many confusing choices.

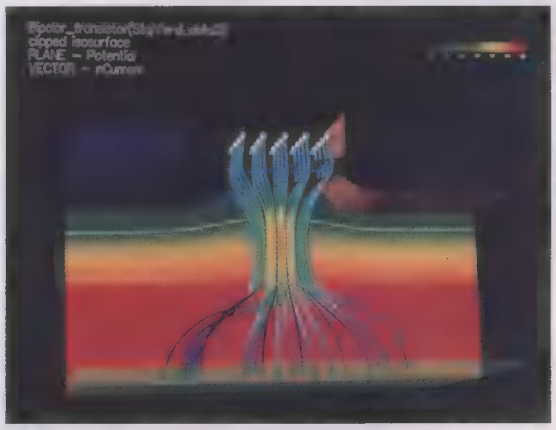
VDA is a multidimensional form of data analysis. Some users see it as synonymous with interactive graphics. Others view it as a new way to do data analysis. But all are unanimous in agreeing that VDA software, regardless of how or why a person starts using it, will accelerate the analysis and discovery process.

Whether increasing productivity is assumed to mean getting faster results or getting better results, users of VDA software find themselves spending less time managing data and more on analysis and discovery. VDA transforms data analysis into an interaction between data and analyst, whereby the analyst is able to select data, divide it into subsets, interpret it, and display some or all of the data at any time.

"Once you understand the physical components of bouncing sound through someone's body and generating an image from that, everything you do after that is nothing more than standard image processing," said Roger A. Pierson, director of Reproductive Biology Research at the University of Saskatchewan, in Saskatoon, Canada. "It's what you interpret from the results of your studies that's important, and that's what PV-Wave [a leading VDA program] has given us: a new way to interpret our data and better ways to manipulate it."

True VDA products reveal several characteristic features. Among them are data presentation tools to graphically analyze data, support for large multidimensional datasets, and a high degree of interactivity. Other VDA tools offer fast data access, subsetting and output; numeric and statistical analysis; and graphics, imaging, tabulating, and animation for data display.

The best products add a programmable language or macro capability, which automates repetitive tasks and helps developers build complete applications for end-users. The best products also have excellent and flexible presentation graphics, to enable the user to present the findings



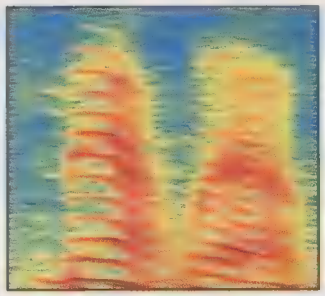
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IBM Corp.'s Visualization Data Explorer helps to portray the flow of electrons in a bipolar transistor, with different colors indicating changes in the current's magnitude. The electric potential in a cross-sectional plane is shown so as to depict current focusing. (Data courtesy of Robert Dutton, Stanford University.)

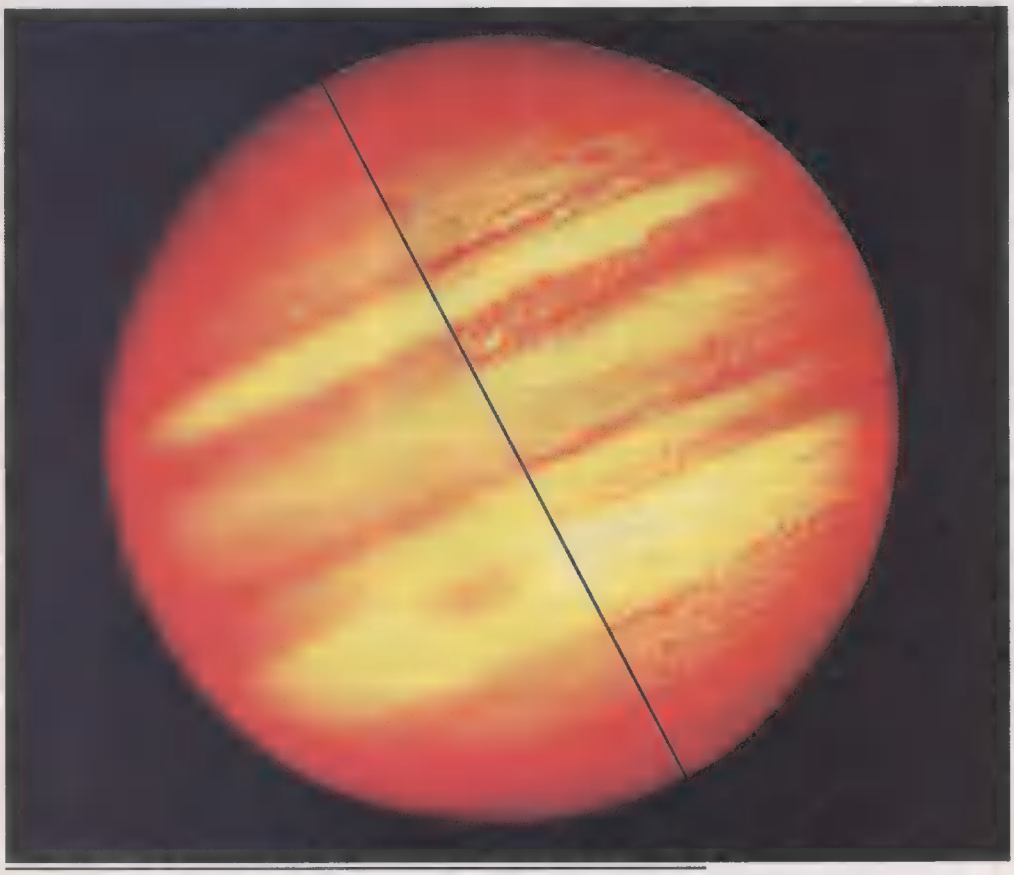
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This blurred image of Jupiter (left side), produced by the Hubble Space Telescope before its repair, was corrected with the MATLAB Image Processing Toolbox and MATLAB's numeric processing power using an iterative restoration technique (right side). Data courtesy of Dr. S. J. Reeves, Auburn University.

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With an extensive function set, application-specific toolboxes, and an intuitive language, MATLAB is the natural environment for solving problems and expressing technical concepts.

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With MATLAB, you can crunch huge data sets and perform complex numeric and symbolic computations, quickly and accurately.

Revealing graphics to sharpen your insight

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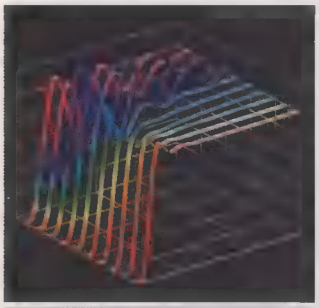
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Powerful GUI tools let you create interactive displays, prototype modules, and build entire applications.

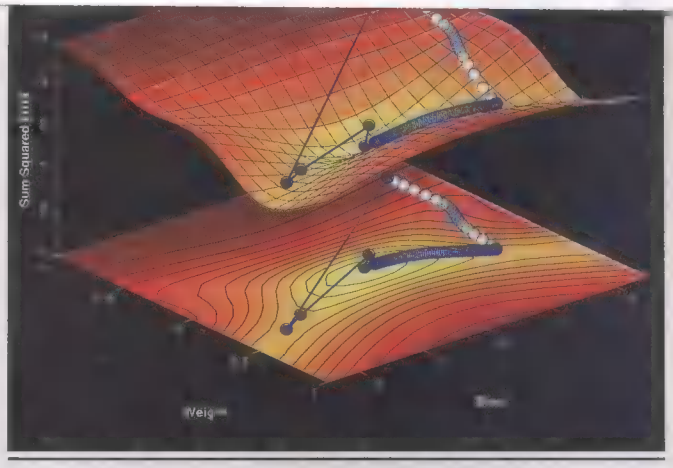
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- *Nonlinear Control Design*
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- *μ-Analysis and Synthesis*
- *Model Predictive Control*
- *System Identification*

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- *Neural Networks*
- *Symbolic Math (with Maple V)*
- *Statistics*
- *Optimization*
- *Splines*

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- *Apply nonlinear simulation and optimization methods*
- *Built on SIMULINK block diagram paradigm*

Image Processing Toolbox

- *Advanced 2-D filter design, restoration, and enhancement*
- *Block processing and nonlinear filtering*
- *Image analysis and transforms*
- *Color, geometric, and morphological operations*

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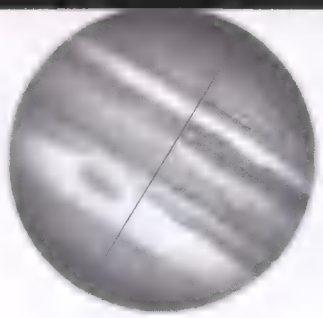
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Switzerland: +41-31-998-44-11 • Taiwan: +886-2-501-8787
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☐ Signal Processing	☐ Simulation	☐ Optimization
☐ Image Processing	☐ Control System Design	☐ Statistics
☐ Symbolic Math	☐ Real-Time Control	☐ Splines
☐ Neural Networks	☐ System Identification	☐ Chemometrics

Computer Platform – check all that apply:

☐ PC ■ Macintosh ☐ UNIX Workstation ☐ VAX ■ Supercomputer

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COMPANY _____

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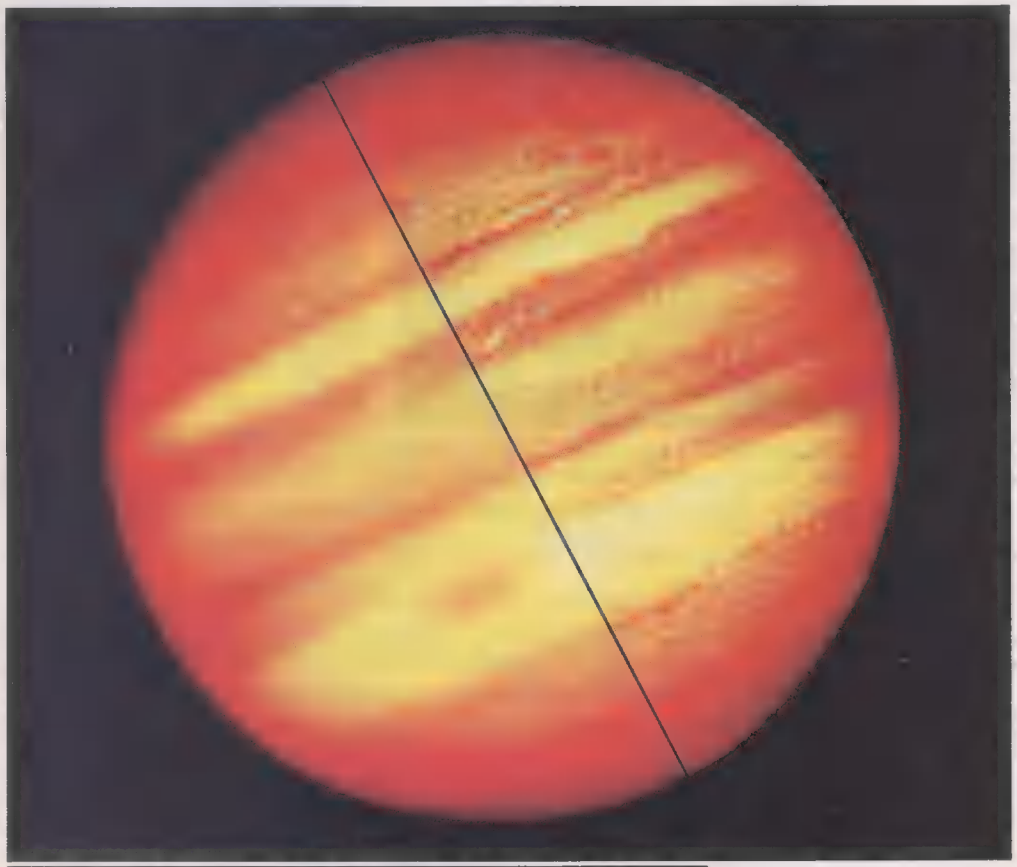
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This blurred image of Jupiter (left side), produced by the Hubble Space Telescope before its repair, ■■ corrected with the MATLAB Image Processing Toolbox and MATLAB's numeric processing power using an iterative restoration technique (right side). Data courtesy of Dr. S. J. Reeves, Auburn University.

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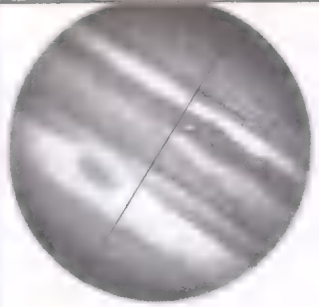
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☐ Neural Networks	☐ System Identification	☐ Chemometrics

Computer Platform – check all that apply:

☐ PC or Macintosh ☐ UNIX Workstation ☐ VAX or Supercomputer

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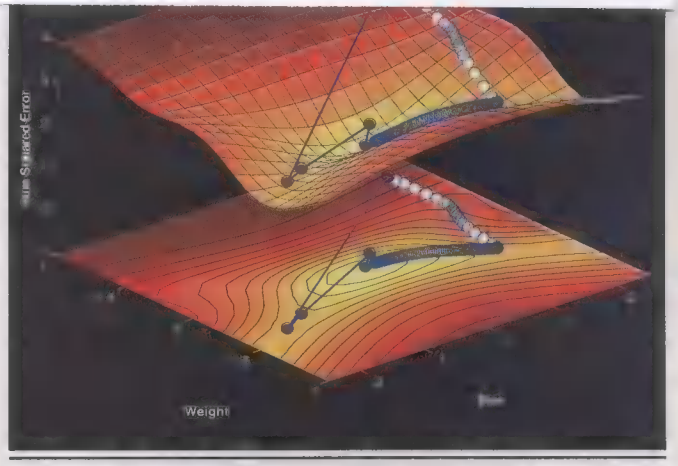
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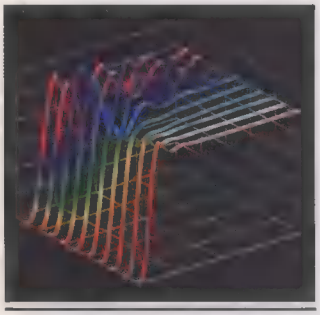
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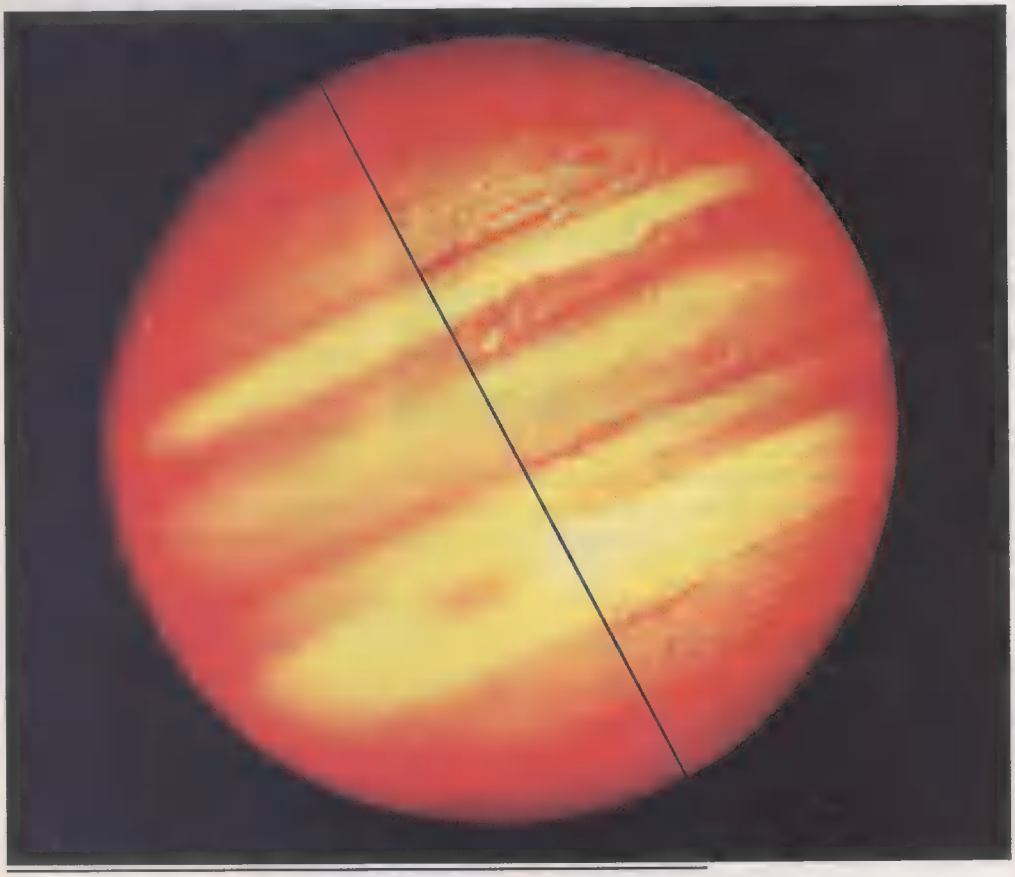
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MATLAB

An open system for application development

With MATLAB's open approach, you can tailor any feature to your needs. You can inspect source code and algorithms, change existing functions, or add your own.

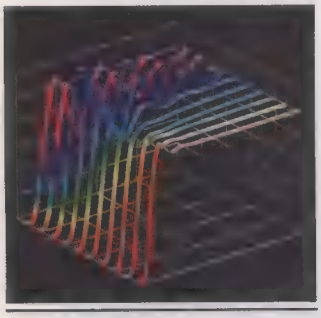
MATLAB fits into your current computing environment. You can dynamically link MATLAB with your C or Fortran programs, exchange data with other applications, or embed MATLAB as an analysis and visualization engine.

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Image Processing Toolbox with floating-point power

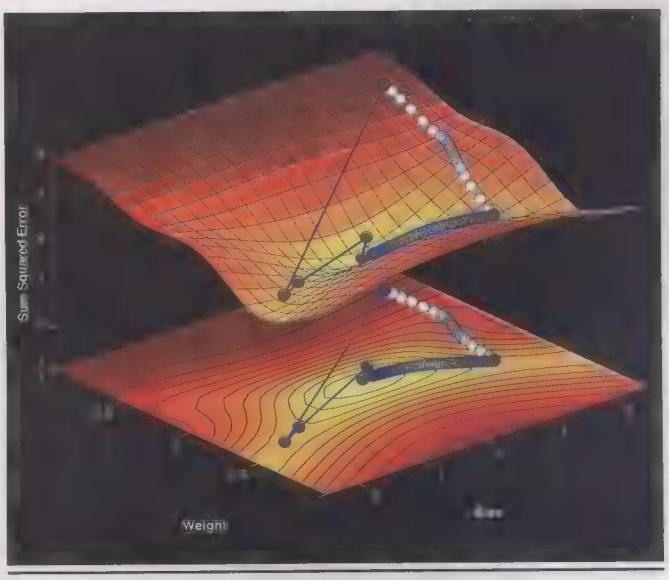
With the Image Processing Toolbox, you can treat image data both visually and numerically. It gives you the resources you need to view, analyze, and manipulate images and 2-D signals. Techniques include image enhancement, restoration, filtering, and statistical analysis.

Control system engineering toolboxes

MATLAB and SIMULINK® provide the most comprehensive environment for analyzing, designing, simulating, and implementing control systems.

SIMULINK allows you to model the behavior of complex nonlinear systems and interactively monitor simulation results using block diagrams. Real-Time Workshop™ adds code generation and a development environment to rapidly implement and test designs on the real-time hardware of your choice. The control family of toolboxes includes:

- *Control System Design*
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Data analysis and visualization software

Name	Platforms	Package description	Comments	Related packages
Abacus Concepts, Berkeley, CA; 510-540-1949; fax, 510-540-0260				
StatView Circle No. 178	Macintosh: Version 4.0 IBM-type PC: N.A. Unix workstations: N.A. Other: N.A.	Combines data management and analysis, graphing, drawing, and color presentation	—	Statistical software, including SuperAnova, QC Tools, Survival Tools, Mac Spin
Advanced Visual Systems Inc., Waltham, MA; 617-890-4300; fax, 617-890-8287				
The Application Visualization System (AVS) Circle No. 179	IBM-type PC: Q2, '95 Unix workstations: $6500+	Flexible, platform-independent visualization environment for interactive graphics applications	Displays 2- and 3-D images, 3-D graphics, and multidimensional data with broad range of visualizing techniques; over 230 modules support visualization, imaging, and graphics functions	AVS/Animator
AVS/Express Circle No. 180	IBM-type PC: call vendor, Unix workstations: call vendors	Multi-platform application development environment; rapid prototyping and deployment of applications, using visual programming	State-of-the-art technology for graphics, visualization, and imaging	AVS 5
Toolmaster Circle No. 181	IBM-type PC, Unix workstations: call vendors	Toolmaster agX is an application-level visualization library integrated with the X Windows system; contains functions for analyzing and presenting numerical data	Toolmaster UIM/X combines the agX library and Toolmaster widgets into an environment for developing visualization applications; Toolmaster widgets extend the Motif widget set with others customized for data visualization	Toolmaster widgets and UIM/X

with traditional analytical graphics.

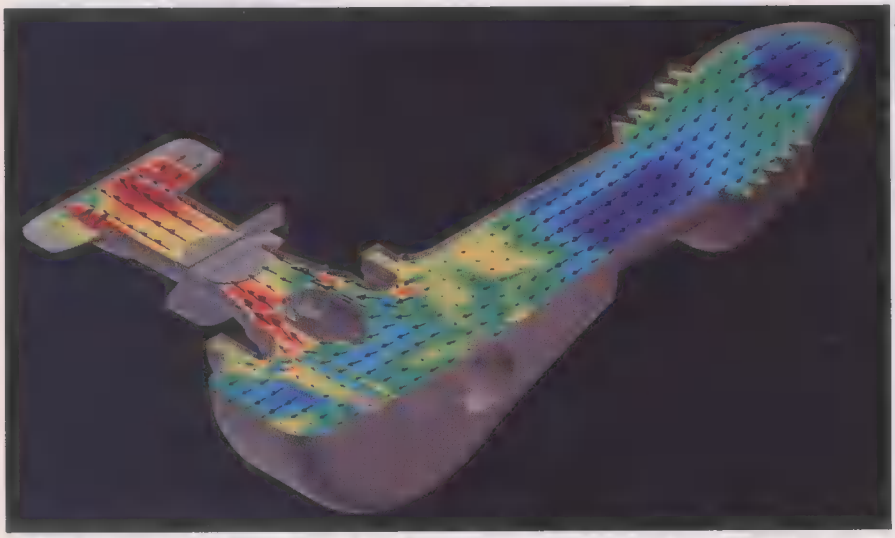
More and more scientists, engineers, and researchers in almost every field from astronomy to zoology are using visual data analysis tools and techniques, of the kind listed in the accompanying table.

To begin with the field of oil and gas: the sizes, shapes, and locations of oil reservoirs are being modeled by Intera Information Technologies Ltd. in a fraction of the time formerly required, now that traditional graphics have been replaced with a VDA package from Advanced Visual Systems. (Another example is VoxelGeo, a package from Vital Images that combines interactive volume rendering of 3-D seismic data with geometric modeling.)

In transportation, new rail car systems and components are being designed by mechanical, civil, and industrial engineers with the aid of PV-Wave from Visual Numerics Inc. Meanwhile, in aerospace, engineers at leading jet engine manufacturers are employing FieldView from Intelligent Light Corp. to design turbo pumps and engines [Fig. 1]. And in manufacturing, quality control engineers are making use of Pirouette from InfoMetrix Inc. to evaluate assembly line motors and schedule their maintenance.

In the area of medicine, researchers are applying ApeIII from TaraVisual Corp. to the analysis of magnetic-resonance imaging data, while biomedical researchers at the Harvard School of Public Health are using VoxelView to study the structural components within human cells. Others are using Matlab from The MathWorks to design a system that assists surgeons to install bone implants; the system can model the performance of artificial limbs on a particular patient and evaluate how implants cause stress to bones and muscles, so that surgeons may optimize the performance and type of implant they use.

In telecommunications, network engineers are using MacPhase by Otter Solutions to visually slice through terrain maps, in order to position microwave repeaters that require a direct line of sight between them. And scientists at Lockheed's Solar and Astrophysics Laboratory are using IDL from Research Systems Inc.



Intelligent Light Corp.

[1] The direction and magnitude of gas flow in an intake manifold are depicted by vectors using FieldView software by Intelligent Light Corp.

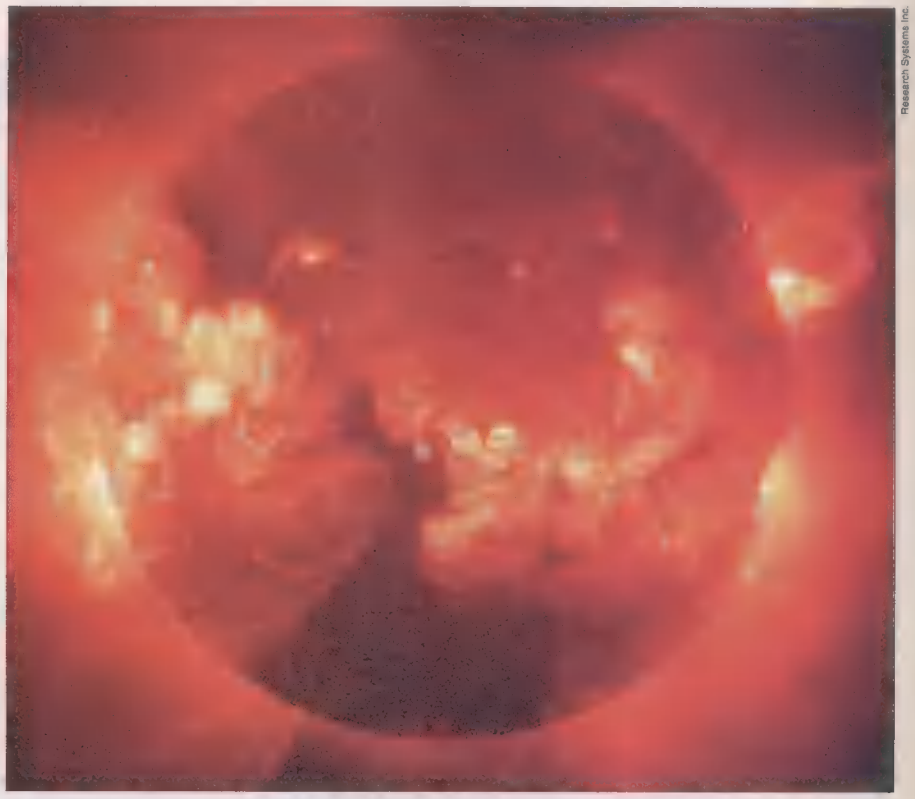
to analyze satellite data and the sun's magnetic field [Fig. 2].

Electronics engineers, not to be left out, are employing BBN/Cornerstone from BBN Software Products Corp. to predict the yields of printed-circuit board production lines.

COMPARING PACKAGES. The biggest challenge for VDA software buyers is decoding the jargon and terminology used by software developers. How does a VDA tool differ from a "visually oriented analytical graphics software package"? Do pie charts count as VDA? The answer is that almost every developer of data analysis software claims to do data visualization, but there are enormous differences between packages, and users should exercise caution in evaluating them.

According to John Sammis, vice president at Data Description Corp., visual data analysis should enable scientists, engineers, and researchers to do more than just depict a complex physical process like the thrust from a jet engine color-coded by temperature. "Nonphysical concepts can benefit from visualization techniques, too. What should a graph of, say, the response of a patient to a drug therapy look like?"

Before an organization buys VDA software, those evaluating it should call the developers or their representatives, describe the application, and ask for names of



Research Systems Inc.

[2] Plasma at a million degrees surrounding the sun is visualized with IDL software. This image employs data from a charge-coupled device (CCD) camera and a soft X-ray telescope built by Lockheed Corp.'s Solar and Astrophysics Laboratory and flown on Japan's Yokoh satellite.



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Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Rebated packages
Amtec Engineering Inc., Bellevue, WA; 1-800-676-7568, 206-827-3304; fax, 206-827-3989; e-mail, tecplot@moclips.amtec.com				
Tecplot + 3DV 6.0 Circle No. 182	IBM-type PC: $699+ Unix workstations: $2195+ Other: call vendor	Interactive plotting program; XY, 2-, 3-D surface, and 3-D volumetric plots; general multi-block mesh structures including IJK and 3-D FE	Allows creation of isosurfaces, 3-D streamlines, and arbitrary slices of multiple volumes of data	Extended version; includes all features of Tecplot 6.0 (*XY*, 2- and 3-D surface plots)
Tecplot 6.0 Circle No. 183	IBM-type PC: $649+ Unix workstations: $1695+ Other: call vendor	Interactive plotting program; XY, 2- and 3-D surface plots; mesh contours, vectors; general multiblock mesh structures, including triangles and quads	Extensive 2- and 3-D surface contouring options; allows animation; triangulates random data; can run in batch mode	
Aptech Systems Inc., Maple Valley, WA; 206-432-7855; fax, 206-432-7832; e-mail, info@aptech.com				
Gauss Circle No. 184	IBM-type PC: $995+ Unix workstations: $1995+ Other: call vendor	Math and statistical visualization and analysis environment built around a fast, extendable, interactive array language	Hundreds of built-in math functions including linear algebra routines; comprehensive 2- and 3-D publication-quality graphics with color PostScript output; latest version adds speed, 32-character symbol names, ASCII-character string arrays, improved file I/O, 2-D FFTs; version available for Pentium PCs	Application packages include statistics, econometrics, engineering, signal processing, simulation, behavioral studies, operations research, and finance
Gauss Applications Circle No. 185	IBM-type PC: $95+ Unix workstations: $195+ Other: call vendor	Consists of 10 packages written in Gauss for linear regression, log/linear analysis, descriptive statistics, linear programming, optimization, maximum likelihood estimation, event count and duration regression, quantal response, time series, autoregression, Arima models, nonlinear equations, nonlinear curve-fitting	Requires Gauss	Packages available for control systems, queuing, statistical analysis, and signal processing
Sim Gauss Circle No. 186	IBM-type PC: $375 Unix workstations: available in 1995 Other: Convex	Nonlinear dynamic simulation package	Requires Gauss	See above
BBN Software Products Corp., Cambridge, MA; 617-873-2678; fax, 617-873-6153; e-mail, bmerrey@bbn.com				
BBN/Cornerstone Circle No. 187	Unix workstations: $1795+	Exploratory data analysis software for engineers that is easier to use and more powerful than a spreadsheet; integrates data access, visualization, and analysis and presentation of results	Latest Release 1.2 added Cornerstone Extension Language (CEL)	—
RS/Series Circle No. 188	Macintosh: N.A. IBM-type PC: $595+ Unix workstations: $2000+ Other: $2000+	Series includes customizable set of products for such applications as data analysis and graphics (RS/1), exploratory statistical analysis (RS/Explore), design of experiments (RS/Discover), and statistical quality control (RS/QCII)	New interprocess communications and statistical capabilities, easy data access	Data from data analysis and graphics packages easily transfer to BBN/Cornerstone

Active data analysis

(Continued from p. 65)

experienced users to contact and question. Since each package has features that serve its core application areas best, it's advantageous to find the best package for the job. For example, the best of today's statistical analysis packages may have VDA features specific to the types of analyses statisticians are likely to perform—but these are different from those an electronics engineer would require.

According to Jon Peck, vice president for technology at SPSS Inc., developers of SPSS for Windows, researchers turn to visualization when they have to deal with large quantities of data with many dimensions or variables. "Highly dimensional data, for example, 6-D data, is hard to look at graphically or numerically. But using a statistical analysis program like SPSS, you could fit a statistical model to the data to describe it."

SPSS for Windows, like S-Plus, Statgraphics, Systat, and many other statistical analysis packages, includes several graphs for VDA. Real-time 3-D rotation of scatterplots is popular for viewing data from an unlimited number of perspectives. Scatterplot matrices, a multidimensional graph liked by statisticians, enable users to view multidimensional data as a cubic array of scatterplots.

Further insights into data may be gathered from statistical plots such as Centroids and Chernoff faces (a graph that displays information as "human" faces with different features). Apple Computer Inc.'s QuickTime animation program (included in the Macintosh operating system) is utilized by Systat in making the Mac play "movies" of a model, to simulate its graphical results even as one or more variables are being changed continuously.

3-D RENDERING AND BEYOND. The modes being offered today for visual data analysis are many and varied. They make 3-D rendering possible, as well as shadowing from multiple light sources, animation, and much else. For example:

- 3-D rendering converts a wire-frame schematic into a "solid."
- A multiplicity of light sources affords a perspective view from any position with true-to-life shadows.
- Animation turns a series of graphs into a real-time "movie."
- Pan and zoom changes the viewpoint and "navigates" through a graph or image.
- Isosurfaces and slice planes can "cut" through a graph or image along any coordinates to view or select the data found there.
- Vector fields can indicate flow or force at points on a surface or grid in a graph.
- Noise reduction, thresholding, and other image analysis techniques allow users to adjust the intensities of image parameters to reveal new perspectives or views of underlying objects.
- Area measurement includes tools for measuring the size of parts of a graph or image.
- Point probes include tools for showing data point values on a graph or image.
- Annotation refers to the ability to add notes to a point or part of a graph or image.
- Mirroring shows the enantiomer (mirror image) of a graph or image.
- Mathematical and statistical functions help in manipulating and transforming data.
- Data acquisition tools take data from experiments and sensors and input it directly.

(Continued on p. 72)

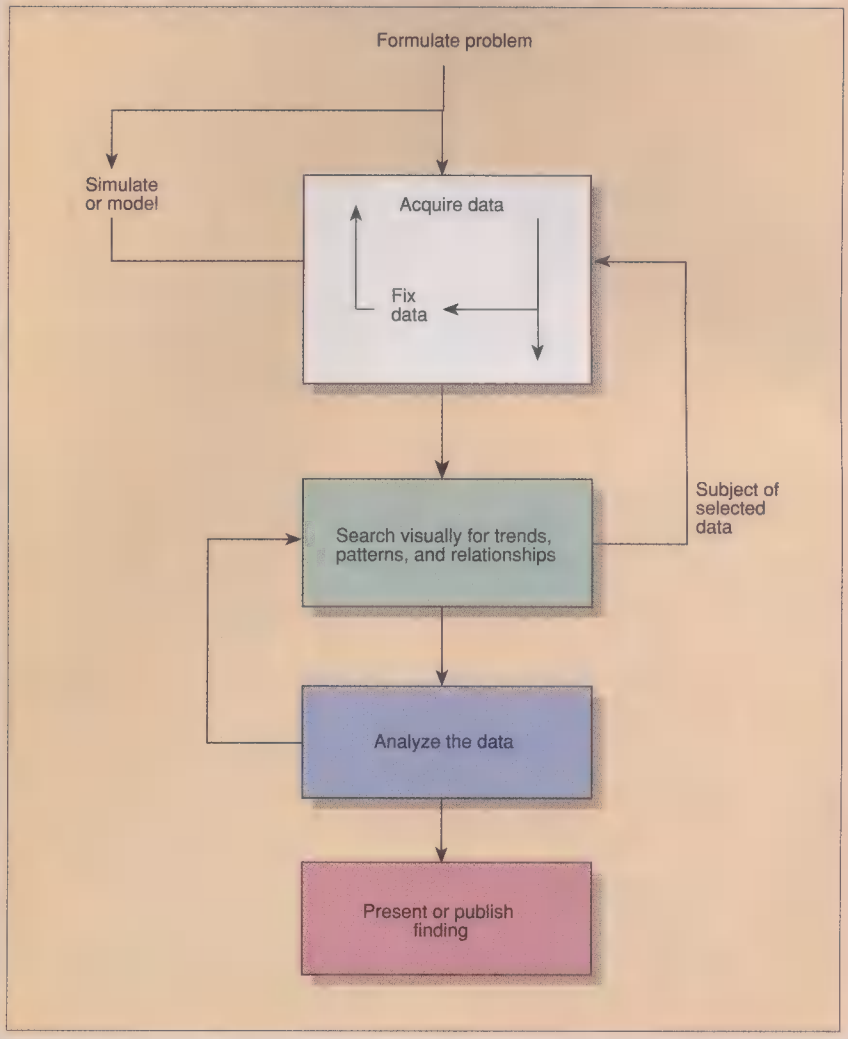
How the 'visual' fits into data analysis

The first phase of the data analysis process is to format the data to suit the available tools. Many researchers say this is often the most agonizing and time-consuming part of the process.

Next comes the visual search phase, in which data is variously displayed to help search for possible clues about patterns, trends, and outliers (data outside a main cluster). Visualization technology's greatest contribution to this phase has been to code data in a variety of relatively simple ways so that it can be displayed in quantity—huge quantities. For example, where a business spreadsheet such as Lotus 1-2-3 or Excel can handle 256 columns by 64 000 rows of data, Spyglass's Plot can handle 32 000 columns by an unlimited number of rows.

Numerical data analysis, often packaged with the VDA tools, also plays a key role in the overall process of data analysis. After preliminary patterns and trends are identified visually, large datasets can often be reduced to smaller, more focused subsets that may be analyzed with statistical and mathematical techniques. For example, researchers working with satellite data were swamped under years of 24-bit atmospheric data collected at rates of 10 MB–100 MB per hour. So using Visual Numerics' PV-Wave, they are condensing it all into tell-all animations that will play in minutes and that require only 5–10 MB of storage.

Finally, data presentation tools enable the user to take the results of both the visual and the numerical analyses and combine them into a succinct format. —*K.K.*



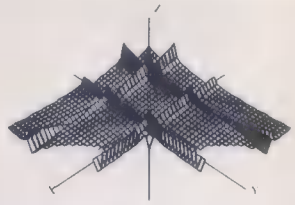
Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Biosoft, Ferguson, MO; 314-524-8029; fax, 314-524-8129				
Fig. P Circle No. 189	IBM-type PC: $499	Scientific graphics and numeric processing and analysis package	Data presentation and analysis for publication and slide presentation	—
BMDP Statistical Software Inc., Los Angeles, CA; 1-800-238-2637, 310-207-8800; fax, 310-207-8844				
BMDP Classic 7.0 Circle No. 190	IBM-type PC: $495+ Unix workstations: $995+ Other: $1295+	Comprehensive statistical analysis system including powerful command language and advanced statistical capabilities	File import/export, data entry and management, plots, extensive library of statistical modules	BMDP New System for basic data analysis and statistics; BMDP/Diamond for multidimensional data visualization
BMDP/Diamond 1.0 Circle No. 191	IBM-type PC: $695 Unix workstations: $695	Highly interactive system for graphical exploration and visualization of relationships in multivariant data	Using color and a powerful collection of 2-, 3- and multi-D data visualizations, the user interactively explores relationships in multidimensional datasets	See above
BMDP New System 1.0 Circle No. 192	IBM-type PC: $395	Interactive, easy-to-use data analysis and basic statistics for the nonstatistician	Statistics, up through Anova and multiple regression, dynamically linked to plots and data in a Windows program	See above
Civilized Software Inc., Bethesda, MD; 800-672-6522, 301-652-4714; fax, 301-656-1069				
MLAB Circle No. 193	Macintosh: $1995 IBM-type PC: $1495 Unix workstations: $2995 Other: NextStep (on Motorola and Intel platforms), $2995	Advanced math and statistical modeling system applicable to many data analysis and experimental math problems	Has 400+ built-in functions, including many unusual ones like Voronoi diagrams; solves and curve-fits differential equations; provides 2- and 3-D graphics plus color PostScript output	—
CoHort Software, Minneapolis, MN; 800-728-9878; fax, 612-825-3944; e-mail, 71161.564@compuserve.com				
CoStat Circle No. 194	IBM-type PC: $159	General-purpose menu-driven statistical package	Geared to scientists, not statisticians; wide selection of procedures; connections to other programs	CoPlot, for 2- and 3-D graphs; CoDraw, for technical drawings; CoVis, for animated graphs
CoVis Circle No. 195	IBM-type PC: $159	For making animated scientific graphs to view data that changes with time	Offers unusual ways to visualize large or dynamic data sets	See above
CoPlot Circle No. 196	IBM-type PC: $159	For making publication-quality 2- and 3-D scientific graphs	Flexibility enables user to get exactly the graph needed	See above
Data Description Inc., Ithaca, NY; 607-257-1000; fax, 607-257-4146; e-mail, datadesk@applelink.apple.com				
Data Desk 4.2 Circle No. 197	Macintosh: $595	Fast visual data analysis and statistics package	Extensive exploratory and visual tools; Power Macintosh accelerated	—
Delta Point Inc., Monterey, CA; 800-446-6955; fax, 408-648-4025; e-mail, America On-Line: Delta Point, MCI: 495-9962				
Delta Graph Pro Circle No. 198	Macintosh: $195 IBM-type PC: $195	Extensive data import and linking; produces more than 60 charts including quality, control histograms, scatter plots, contours, vector, ternary, 3-D, and XYZ; curve, fitting	Template libraries store custom charts and graphs; chart advisor offers help in selecting charts; intuitive interface	—

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Digital Optics Ltd., Auckland, New Zealand; (64+9) 478 5779; fax, (64+9) 479 4750; e-mail, 100237.423@compuserve.com				
V For Windows Circle No. 199	IBM-type PC: $1995	Advanced image-enhancement and analysis package with support for 16-bit-plus and floating-point images	Powerful scripting language supports multiple types, complex numbers and images; processes image expressions directly; 32-bit processing; extensive object shape analysis and counting; Fourier domain enhancement	Company's series of high-end imaging packages
DSP Development Corp., Cambridge, MA; 800-424-3131, 617-577-1133; fax, 617-577-8211; e-mail, dspdev@world.std.com				
DADiSP Circle No. 200	IBM-type PC: $1895 Unix workstations: $4495+ Other: $4495+	Data analysis and visualization tool for scientists and engineers	DADiSP acquires inputs and generates sample data, displaying the results in multiple windows for immediate graphic comparison	Member of the DADiSP family of data analysis and visualization software
DADiSP/Filters Circle No. 201	Macintosh: N.A. IBM-type PC: $495 Unix workstations: $995 Other: $995	Latest version greatly increases number of functions available to design, analyze, process, and display both FIR and IIR digital filters	Easy-to-use tool allows scientists and engineers to do sophisticated filtering without programming	See above
DADiSP/Stats Circle No. 202	Macintosh: N.A. IBM-type PC: $495 Unix workstations: $995 Other: $995	Data analysis and visualization tool for scientists and engineers	Module for computing statistical measurements, calculating probability values, and performing hypothesis testing on sample data	See above

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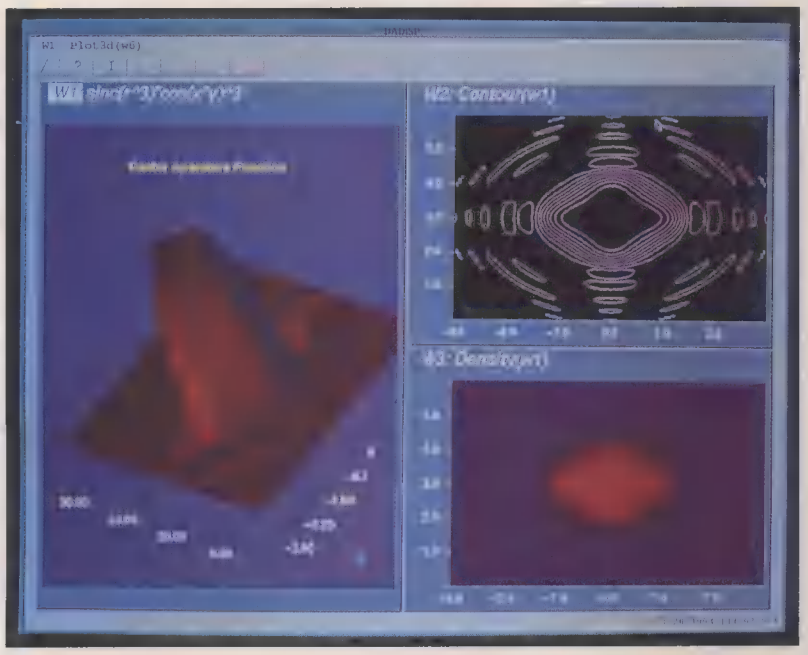
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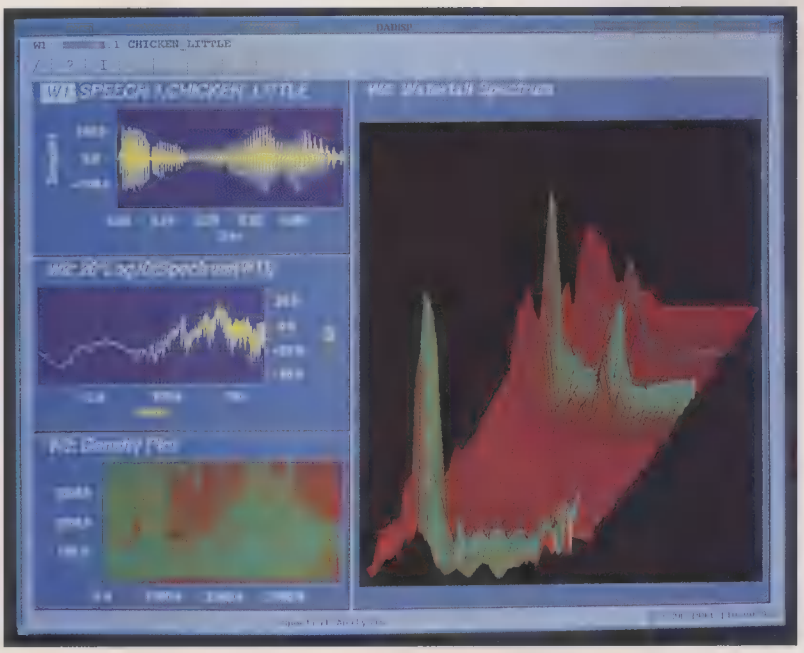
Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Harmonic Software Inc., Seattle, WA; 206-367-8742; fax, 206-367-1067; e-mail, harmonic@world.std.com				
O-Matrix 2.0 Circle No. 203	IBM-type PC: $395+	High-performance visual data analysis package with extensive numerical analysis capabilities, a simple matrix language with an integrated debugger, and publication-quality interactive graphics	Windows interface simplifies data analysis; complete 32-bit application for high performance	—
Hyperception Inc., Dallas, TX; 214-343-8525; fax, 214-343-2457; e-mail, info@hyperception.com				
Hypersignal for Windows Circle No. 204	IBM-type PC: $1495+	Signal-processing design and analysis package; real-time data acquisition and DSP board support; graphical simulation and code generation	Comprehensive data and graphical analysis capabilities with advanced DSP functions executed in real time	Part of the Hypersignal software series
IBM Corp., Hawthorne, NY; 914-784-5106; fax, 914-784-5077; e-mail, raypa@watson.ibm.com				
IBM Visualization Data Explorer Circle No. 205	Unix workstations: $5900+	Supports analysis and 3-D visualization of data from modeling, simulation, experiments, or combination; also supports parallel distributed computing on networks, workstation clusters, distributed-memory systems, and shared-memory multiprocessors	Runs as a client-server application with all tasks managed as a single process on each workstation; provides uniform access and services to data independent of type or structure; employs a visual programming and data-flow approach to visualization; supports application areas such as chemistry, GIS petroleum/geographical prospecting, medical, environmental, and financial modeling	—
InforMetrix Inc., Seattle, WA; 206-441-4696; fax, 206-441-0841				
Pirouette Version 1.21 Circle No. 206	IBM-type PC: $4000	Multivariate data analysis; interactive graphics with 3-D plotting; classification regression calibration; data exploration	Raw and calculated data are tracked in a single file; raw data and result plots are hot linked for dynamic pattern recognition	The company has been specializing in multivariate analysis software since 1978; other packages include Arthur and Ein*Sight
Intec Controls Inc., Walpole, MA; 508-660-1221; fax, 508-660-2374				
Paragon TNT Circle No. 207	IBM-type PC: $1295+	For data analysis and visualization of industrial processes	Allows real-time graphical display of process dynamics; provides a comprehensive library of analysis functions, including math, logic, and string manipulation	—
Integrated Systems Inc., Santa Clara, CA; 408-980-1500; fax, 408-980-0499; e-mail, wcavanaugh@151.com				
Xmath Circle No. 208	Macintosh: N.A. IBM-type PC: $2000 Unix workstations: $2500 Other: $2500	2- and 3-D interactive color graphics; object-oriented graphics and analysis package; has high-level scripting language; built-in graphical and programmable user-interface, interactive debugger	Has more than 200 predefined functions and operators for plug-and-play calculation; scripting tools accelerate algorithm development; object classes for efficient data management, ease of use and fast model execution	Supports eight special-purpose modules for control design, optimization, signal analysis, and more; fully integrated with the Matrix$_x$ family, which includes System Build for visual modeling and simulation, AutoCode and Document it for automatic code and document generation, and RealSim Series hardware for rapid prototyping and real-time simulation and test
Intelligent Light, Lyndhurst, NJ; 201-460-4700; fax, 201-460-0221; e-mail, sww@ilight.com				
FieldView Circle No. 209	Unix workstations: $8500	CFD postprocessor designed to increase productivity in fluid dynamic engineering by simplifying investigation of complex 3-D data	Visualization tools include cutting planes, contouring, streamlines, iso-surfaces, 2-D line plots, data probes, and animation	Fully compatible with leading CFD solvers

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Data analysis and visualization software *(continued)*

Name	Platforms	Package descriptions	Comments	Related packages
Jandel Corp., San Rafael, CA; 800-4-Jandel, 415-453-7782; e-mail, sales@jandel.com				
PeakFit Circle No. 210	IBM-type PC: $595	Uses sophisticated nonlinear curve-fitting techniques to separate and characterize unresolved peaks in an X, Y dataset	Graphical control of parameter values enables manipulation of individual peaks	—
SigmaPlot Circle No. 211	Macintosh: $295 IBM-type PC: $495	Customizes virtually all graph attributes, including 2- and 3-D graph types, technical axis scales, multiple graphs on a page, and multiple plots on one graph	Produces presentation graphics, data analysis, curve-fitting, graph annotation	—
SigmaStat Circle No. 212	IBM-type PC: $495	Statistics package for the nonstatistician; guides the user through an analysis, advising which tests are appropriate for the data	Automatic assumption checking; handles "messy" data; provides detailed report	—
TableCurve 2D Circle No. 213	IBM-type PC: $495	Uses automated statistical methods to curve fit over 3400 built-in linear and nonlinear equations to an X, Y dataset	Ranks equations according to user-defined criteria; generates graphs and ready-to-compile code	—
TableCurve 3D Circle No. 214	IBM-type PC: $495	Uses automated statistical methods to surface fit over 450 million equations to an X, Y, Z dataset	Generates graphs and ready-to-compile code	—
Keithley MetraByte Division , Keithley Instruments Inc., Taunton, MA; 800-348-0033; fax, 508-880-0179				
Asyst 4.0 Circle No. 215	IBM-type PC: $2195	Extendable programming language for data acquisition and analysis and graphics	Options on copy protection; site and run-time licenses available	Company's Easyest LX, which provides graphical user-interface and file compatibility
TestPoint Circle No. 216	IBM-type PC: $995	For Windows-based test, measurement, and data acquisition applications; has an object-oriented style	For applications involving IEEE-488, RS-232, D/A, A/D, and digital I/O interface controls and data acquisition; includes hundreds of prewritten libraries to interface to popular GPIB devices; contains math functions, graphics, plotting, and annotation tools	Supports company's DAS-1800, DAS-1600, DAS-TC, and other data acquisition hardware

Active data analysis

(Continued from p. 67)

The swiftness of change in VDA is a turn-on for a lot of scientific and technical professionals. They have plenty to choose from. For example, through an agreement with IBM Corp., BMDP is now marketing and supporting BMDP/Diamond, a graphical visualization tool for exploring interactively the relationships within multivariate data. Invented and developed at the IBM Research Division's Thomas J. Watson Research Center, Diamond is available for Unix and OS/2.

BBN/Cornerstone by BBN Software Products is a recent entry into the VDA software field. Its linked graphics and data and many data analysis tools are meant for engineers in manufacturing, quality control, and R&D. The package includes an innovative visual representation of an analysis session that is captured automatically and consists of a "work map" of linked icons [Fig. 3]. Work maps can be edited, saved, and reused. In addition, an object-oriented extension language equips an end-user to build specific data analysis applications. BBN/Cornerstone's options provide direct access to the contents of Sybase, Oracle, Ingres, Informix, and SAS databases.

Another notable enhancement is the Matlab Image Processing Toolbox, which became available during the past year from The MathWorks Inc. It has many new image-processing algorithms.

NEW PLATFORMS, FEATURES. The most popular new platform is, of course, Windows. Visual Numerics Inc. announced versions of its PV-Wave product for Windows and Windows NT. Visual Numerics based its new mathematical and statistical toolboxes for Windows upon the popular IMSL libraries, which have close to 1000 statistical and mathematical functions.

Even Spyglass Inc. is moving its products to Windows. The company developed Dicer, Splicer, Transform, and Plot and has long been a leading supplier of easy-to-use VDA software on the Macintosh and on Unix machines. And at IBM, according to Don Sefton, program director for its Data Explorer visualization product, requests from customers were what drove the port of the product from Unix to OS/2.

Amtec Engineering is planning to augment the Unix and DOS versions of Tecplot with two interfaces—a full Windows one plus support for Win32s (32-bit processing under Windows), as well as a Motif interface for Unix. Most other vendors should follow. Meanwhile, those somewhat

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Viewdac 2.2 Circle No. 217	IBM-type PC: $1995	Windows-oriented package with integrated data acquisition analysis and graphics	For high-performance applications needing precise control of events; allows extensive interactive data analysis concurrent with data acquisition	Supports wide range of Keithley hardware; data is compatible with Asyst and Easyest LX
Visual Test Extensions Circle No. 218	IBM-type PC: $149	Integrated set of Visual Basic custom controls for acquiring, analyzing, and graphing measurement data	Designed for peak performance under Windows; combines with any third-party product for the Visual Basic environment	Replaces company's VisualDAS custom controls for data acquisition
Macsyma Inc., Arlington, MA; 617-646-4550, ext. 23; fax, 617-646-3161; e-mail, info@macsyma.com				
PDEase Circle No. 219	IBM-type PC: $499 Unix workstations: $999	Automates finite-element analysis; solves a wide range of static and time-dependent physical models; excellent adaptive grid generator and automatic error estimator	Solves equations in solid mechanics, heat transfer, reaction/diffusion, fluid mechanics, magnetostatics; includes 75 demonstrations in these and other areas	Macsyma: PDEase reads Macsyma equations
Manugistics Inc., Rockville, MD; 800-592-0050, 301-984-5123; fax, 301-984-5094				
Statgraphics Version 7 Circle No. 220	IBM-type PC: $995	Comprises over 250 system and statistical procedures for analyzing data using extensive, fully integrated, interactive graphics	Completely menu driven, contains on-line help facilities, full-screen editing, and a report writer to analyze statistical data and test ideas	Part of the Statgraphics family of statistical software; targeted at quality control and experimental design
Statgraphics Plus Version 7 Circle No. 221	IBM-type PC: $1595	Integrates powerful statistical analysis capabilities with sophisticated interactive graphics for analyzing statistical data and testing ideas quickly	New features include mixture design, expanded process capability analysis, more macro options, new matrix utilities, and easy spreadsheet access	Has all the advanced features of statgraphics while offering increased speed and dataset size
Statgraphics Plus for Windows, Version 1 Circle No. 222	IBM-type PC: $649	Powerful statistical analysis tool combines a broad range of procedures with interactive graphics; the base system provides day-to-day statistical tools like regression, Anova, multiple-variable analyses, and cross-tabulation	Can automatically save and revise analyses and DDE support, which eliminates the need to import data from a spreadsheet	The newest addition to the Statgraphics family; has four optional add-on modules ($399 each) for quality control, experimental design, time series, and multivariate statistics
Metrica, Inc., Burlington, MA; 617-229-8686; fax, 617-229-5656				
Metrica 4.0 Circle No. 223	Macintosh, IBM-type PC, Unix workstations: contact vendors	Offers integrated data management, analysis, and visualization tools with special features for engineering applications	High-speed proprietary RDBMS for handling large data sets of time-series, arrays, blobs, complex numbers, and other technical data types; complete statistical, signal analysis, and user-definable function libraries; hundreds of graphics options; custom application development tools in 4GL	The Metrica family of high-speed engineering data-management tools
Microcal Software Inc., Northampton, MA; 413-586-2013; fax, 413-585-0126				
Origin Version 3.5 Circle No. 224	IBM-type PC: $495	For scientific and technical graphics and data analysis; complete data management solution for collecting, analyzing, and presenting technical data	Publication-quality output to all Windows-supported devices; allows datasets from multiple worksheets to be plotted on the same XY axis; built-in scripting language	Optional add-ons include user-interface, 3-D contour, data acquisition system, real-time peak-fitting, Axon pClamp, and file utilities modules

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Mihalisin Associates Inc., Ambler, PA; 215-646-3814; fax, 215-643-4896				
TempleGraph 2.6 Circle No. 225	Unix workstations: $1290	Integrated package for analyzing one or many X-Y datasets and producing publication-quality graphs	Unique "visual vary" feature presents effects of varying fit or transformation parameters; has C and Fortran interfaces	TempleGraph's point-and-click capabilities can also be called from user's C or Fortran using Mihalisin's Partners Plan software
TempleMVV Circle No. 226	Macintosh: $50 000+ IBM-type PC: $50 000+ Unix workstations: $50 000+	Analyzes very large multidimensional datasets in seconds	Uses robust visual analysis methods that are independent of the nature of the distribution function	—
MGA Software, Concord, MA; 508-369-5115; fax, 508-369-0013; e-mail, ficaro@mga.com				
ACSL Vision Circle No. 227	Unix workstations: $3000	Visualization and animation software linked to ACSL (the Advanced Continuous Simulation Language)	This graphics toolkit allows the representation of data in pie and bar charts, instrument arrays, and control panels; has a full set of input objects such as sliders, disks, and buttons useful for the command of simulated data	Member of the company's software family for the analysis of modeling and simulation of dynamic systems
Momentum Data Systems; Costa Mesa, CA; 714-557-6889; fax, 714-557-6969				
DSPworks Circle No. 228	Macintosh: $495 IBM-type PC: $495 Unix workstations: $2000	Signal acquisition and analysis system	Menu-driven signal acquisition supports more than 35 boards; extensive analysis and DSP functions for signal processing	Company's QEDesign for digital filter design
National Instruments Inc., Austin, TX; 512-794-0100; fax, 512-794-8411				
HiQ Circle No. 229	Macintosh: $695	Object-based numerical analysis software provides an integrated graphical environment for solving real-world problems	Has 600 math functions; publication-quality output; interactive 3-D graphics; scripting language; compiler; set of application-specific problem solvers	Company's LabSuite, HiQ, and LabView packaged together, $2395
Numerical Algorithms Group Inc., Downers Grove, IL; 708-971-2337; fax, 708-971-2706				
IRIS Explorer Circle No. 230	Macintosh: N.A. IBM-type PC: N.A Unix workstations: $4000 for four users Other: Cray, $30 000, unlimited users	A complete object-oriented visual programming environment for developing scientific and engineering applications quickly and intuitively	Extensive point-and-click module suite for data input, reduction, and rendering aids in rapid application development	Company's family of products for numerical, symbolic, and visual analysis
Otter Solution, Whitesboro, NY; 315-768-3956; fax, 315-736-4371				
MacPhase Extensions Circle No. 231	Macintosh: $20+	Extension packages for Apple Computer's MacPhase provide data acquisition and analysis and additional file import	Various code plug-ins extend MacPhase	MacPhase, a data analysis and visualization application for 2-D data arrays
Quantitative Technology Corp., Beaverton, OR; 503-626-3081; fax, 503-641-6012				
GIS/GPS System Circle No. 232	Macintosh: $2995+ IBM-type PC: $2995+	GIS/GPS and databases for an executive-level information system	Also available are supporting cartographic and demographic databases	Member of company's Geo-series family
Research Systems Inc., Boulder, CO; 303-786-9900; fax, 303-786-9909; e-mail, info@rsinc.com				
IDL Circle No. 233	Macintosh: $1500 IBM-type PC: $1500 Unix workstations: $3000+ Other: $1500	Integrated computing environment for developing custom applications	Math features include built-in numerical recipes, routines, and a statistics library	PV WAVE, MatLab

Active data analysis

(Continued from p. 72)

ahead of the pack—such as The MathWorks, whose Matlab product is already available for Windows—are making theirs ■ "true" windows application by exchanging the command interface for interactive features.

In a second trend, developers are busily adding data analysis and visualization features to their products. Advanced Visual Systems is working on new techniques for viewing multidimensional data, Intelligent Light is enhancing FieldView to handle even larger datasets on smaller machines and to shift the data search for features worth extracting to the computer from the user. The MathWorks is adding features to Matlab that easily handle 3-D data.

HOT STUFF. To say that VDA is hot is a distinct understatement. Most scientific and technical software developers, whether they classify their products as VDA or not, are vigorously adorning their products with VDA features. For example, "SPSS has an ambitious plan to add visualization and graphics to their entire product line," said Jon Peck.

Data analysis features, too, are proliferating. MacPhase from Otter Solutions has added a 3-D rendering macro language and enables users to "plug-in" their own code or third-party products such as Adobe PhotoShop. A new serial general-purpose interface bus (GPIB) interface from the same company enables frame-grabbers to acquire data directly for medical imaging or for audio/visual digitizers.

MacPhase not long ago gained support for several new file formats and AppleEvents for opening images. The principal enhancement, though, is PowerPC support, which increases processing speed.

TechPlot by Amtec Engineering is ■ scarce commodity—one of the few DOS VDA tools on the market. It has been recently enhanced to support grids for finite-element analysis, light source shading, and the removal of hidden lines. Moreover, Techplot's new 3-D option adds volumetric visualization, multiple isosurfaces, and integration through a vector field, not to mention stream ribbons and slicing planes to extract data.

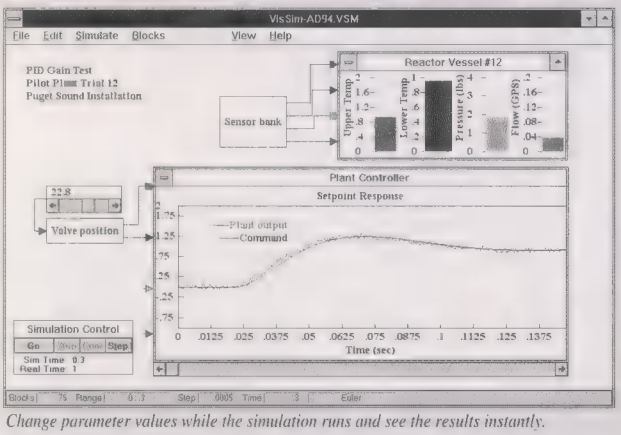
DataDesk from Data Description Corp. today boasts color with which to classify regression lines belonging to different data subsets. With ■ new "hot set" selector, too, the user may define an indicator variable for ■ subset dynamically, in real time. And with new data "sliders," the user may vary on screen the starting parameters for nonlinear line-fitting and thus obtain ■ more intuitive grasp of the effects of ■ parameter on a phenomenon.

VOLUME RENDERING. From Vital Images Inc. has risen VoxelView, ■ VDA package that uses object-oriented volume rendering. Employing data sampled in three dimensions, the technique represents 3-D objects or regions of space as cube-like building blocks called voxels, or volume elements. Each voxel is ■ sample of the original volume and has a numerical value associated with it representing a measured or calculated property of the original object—density, for example, or luminosity, or acoustic reflectivity.

To render ■ view of the original volume, the voxels are projected onto the screen in order, directly building an image of the volume from the entire volume dataset. VoxelView's advanced volume-rendering features include the ability to import geometric contour lines and surfaces for use alongside the voxel data.

Furthermore, such rendering parameters as the opacity of a volume can be so adjusted that both the surface and the internal structures of the data may be viewed simultaneously. The latest version throws in multi-channel rendering—in effect, multiple volumes may be viewed simultaneously in the same rendering window with-

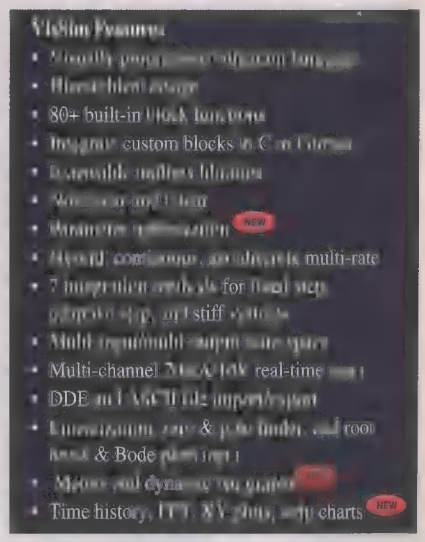
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Circle No. 72

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
SAS Institute Inc., Cary, NC; 919-677-8000; fax, 919-677-8166; e-mail, marg_ann_hansen@mac.sas.com				
JMP Software Circle No. 234	Macintosh: $695 (plus network and annual licenses)	Presents statistics in a graphical environment	Data tables in spreadsheet form are linked to related graphs and tables; offers 3-D spin plots, univariate statistics, and analysis of variance and multiple regression; has quality control and experimental design capabilities	—
The SAS System Circle No. 235	IBM-type PC: $730 first year, $340 renewal Unix workstations: $730 first year, $340 renewal Other: $730+	Provides tools to access, manage, analyze, and present data for enterprise-wide information delivery	Includes tools for graphical data analysis; interactive display of spatially related map data; and 3-D scientific data analysis and visualization; offers interfaces to broad range of hardware	Includes integrated components for EIS, client/server computing, database access, applications development, report writing, and decision support
Scientific and Engineering Tools Inc., Sinking Spring, PA; 610-678-8787; fax, 610-678-8703				
ESPro Circle No. 236	IBM-type PC: $895 Unix workstations: $5000	4GL tool set with graphical user-interface for Sun OS, data analysis, modeling, and simulation with graphics	Provides custom solutions; cost-effective for large jobs; large library of routines; exotic graph papers	—
Scientific Programming Enterprises, Haslett, MI; 517-339-9859; fax, 517-339-4376				
PlotIT 3.1 for Windows Circle No. 237	Macintosh: N.A, IBM-type PC: $495 Unix workstations: N.A. Other: call vendor	For technical data analysis and graphics	Has improved QC capabilities, equation editor; imports Excel 5.0, Lotus, Quattro Pro data files; WYSIWYG fill and line patterns; 80-plus 2-, 3-D QC and specialty graphs available; integrated worksheet for advanced data and regression analysis	A complete package—no additional modules required
Signal Analytics Corp., Vienna, VA; 703-281-3277; fax, 703-281-2509; e-mail, Applelink: D6196				
IPLab Gel Circle No. 238	Macintosh: $750	For gel analysis, densitometry functions, and molecular weight determination; 1- and 2-D analysis techniques	Analyzes dot blots or bands, reports density statistics, identifies peak positions and calculates peak values; reads standard PICT and TIFF files	IPLab Spectrum
IPLab Spectrum Circle No. 239	Macintosh: $1200+	Provides scientific imaging, visualization, analysis, image acquisition and laboratory automation; now in native mode for the Power Mac	Automatically analyzes particles; performs FFTs, image enhancement, densitometry and morphometry; acquires, deconvolves, and displays 3-D serial sections; controls lab equipment	Member of the IPLab family, which includes software for gel analysis, FISH, calcium ratio imaging, and stage and filter wheel control
Prism Circle No. 240	Macintosh: $5600	For powerful image analysis, specifically for microscopy; now in native mode for the Power Mac	Advanced morphometric and statistical analysis features including grain sizes specified in ASTM standard; commands are fully scriptable	—
Signal Technology Inc., Santa Barbara, CA; 805-899-8300; fax, 805-899-4344; e-mail, larry@signal.com				
N!Power Circle No. 241	Unix workstations: $1900+	Object-oriented software for the development, simulation, and deployment of data acquisition, analysis, and graphics applications	Data flow modeling synchronizes analysis processing steps, supports visual programming and simulation through block diagrams; user-supplied code can be bound in as new objects for integrating proprietary algorithms	Imports Matlab, ILS binary, ASCII, and custom data files

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Rebated packages
Spiral Software, Brookline, MA; 617-739-1511; fax, 617-739-4836				
EasyPlot Circle No. 242	IBM-type PC: $349+	Provides fast, interactive, publication-quality graphs of scientific data; helps analyze data visually and mathematically	Recent enhancements include expanded 3-D features and a programming interface so the software can be used as a graphing subroutine callable for user-written Windows applications; handles large datasets quickly	Use with any data acquisition software or with math programs not strong on graphing
SPSS Inc., Chicago, IL; 800-543-2185; fax, 312-329-3668; e-mail, sales@spss.com				
QI Analyst Circle No. 243	IBM-type PC: $695	Complete set of statistical process control statistics, clients, and reports; works with real-time data, as well as data in files	Color-coded graphs for skip floor use; enter assignable causes and action codes; use shewart test or your own rules; set control limits based on standard tables or your specs	Exports data to SPSS (and other packages) for statistical quality control analysis
SPSS Circle No. 244	Macintosh: $695 IBM-type PC: $695+ Others: call vendor	For statistical data analysis and graphics; new 32-bit Windows and Mac versions; Unix versions with Motif, and new developer's kit on Windows	Noted for breadth and depth of statistics and ease of use	Modular product line; add optional modules as needed for the analysis performed
Systat Circle No. 245	Macintosh: $895 IBM-type PC: $895	Advanced statistical procedures and graphics for diverse scientific applications	Noted for scientific and technical graphics and accuracy	Newest member of the SPSS family, Systat balances power and ease of use
Spyglass Inc., Savoy, IL; 800-647-2201; fax, 800-647-2217; e-mail, info@spyglass.com				
Transform 3.0 Circle No. 246	Macintosh: $595+ IBM-type PC: $595 Unix workstations: $595	For visual data analysis; users can import large amounts of data and create surface charts, contour and vector plots, and raster images	A quick and easy tool for analyzing scientific data	—
Statistics Research Center, Soong Sil University, Seoul, Korea; (82+2) 820 0443; fax, (82+2) 824 4383; e-mail, jjlee@krssucc1				
CATS Circle No. 247	IBM-type PC: $20	For teaching statistics and handling modest data-processing projects	Allows experimenting with all theories, including CLT of elementary statistics	—
StatSci, a division of MathSoft Inc., Seattle, WA; 800-569-0123, 206-283-8802; fax, 206-283-8691; e-mail, mktg@statsci.com				
S-PLUS 3.2 Circle No. 248	IBM-type PC: $1450 Unix workstations: $3900	Object-oriented analysis and programming environment for scientific and technical data	Includes over 1650 functions, which provide an interactive, step-by-step approach for classical and modern statistical modeling, mathematical computing, data visualization, and rapid prototyping of analysis solutions; data analyst may control every step of the analysis and extend and customize analysis methods	Family includes add-on modules: ARC/INFO creates a bidirectional data link between ESRI's geographic information system, ARC/INFO, and S-Plus; +Interface allows users to build menu interfaces on S-Plus or access S-Plus like a library of analysis and graphics subroutines; +DOX is for the design of industrial experiments; Plus for Illustra links S-Plus to the Illustra object-oriented relational database

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Steven M. Christensen and Associates, Chapel Hill, NC; 919-967-9853; fax, 919-967-9853; e-mail, stevec@wri.com				
Schur Circle No. 249	IBM-type PC: $500 Unix workstations: $750	Interactive program for calculating properties of Lie groups and symmetric functions; computes Young tableau, plethysms	Powerful and fast, excellent documentation	—
Survo Systems Ltd., Helsinki, Finland; (358+0) 191 8866; fax, (358+0) 449 849; e-mail, seppo.mustonen@helsinki.fi				
Survo 84C Circle No. 250	IBM-type PC: $395	Integrated environment for statistical analysis, data management, spreadsheet computing, matrix algebra, high-quality graphics, and desktop publishing	Unique editorial interface in job control	A 494-page textbook with diskettes of a reduced freeware version is available for $50 plus postage
Synergy Software, Reading, PA; 610-779-0522; fax, 610-370-0548; e-mail, hnath@info.synergy.com				
KaleidaGraph 3.0 Circle No. 251	Macintosh: $249	Sixteen graph structures for plotting up to 20 variables with precise, yet flexible, control of data-display elements; standard and user-defined curve-fits and error bars can be added to graphs	Data can be easily analyzed and modified using formula entry; handles 32 000 points per column; supports AppleEvents and includes a native version for the Power Mac	—
Tara Visual Corp., Columbus, OH; 614-291-2912; fax, 614-291-2867				
apE III Circle No. 252	Unix workstation: $1495+	A scientific visualization software toolkit which allows the conversion of data into 2- and 3-D realistic images and animations	Employs a point-and-click icon-based graphics environment; allows interactive data manipulation and coloring; simplifies the description of data types formats and grids for importing datasets	Developers' version also available
Techni-Soft, Livermore, CA; 510-443-7213; fax, 510-743-1145				
SIGX 3.5 Circle No. 253	Unix workstations: $5000+	Complete environment for signal processing includes more than 200 commands for operations on single and multichannel signals in an interactive, user-friendly environment with a directly accessible database	Operations range from 1- and 2-D transforms to sophisticated parameter and adaptive processor applications; upgraded version includes software development tools, interactive, button, and pull-down menus, and color graphics; powerful database tool for storage, access, and manipulation of data	Algorithmically equivalent to such packages as Matlab, Signal Processing Toolbox, Wave, Monarch Filters, and Hypersignal but with unique database
SSPACK_PC Version 3.0 Circle No. 254	Macintosh: $995 IBM-type PC: $995 Unix workstations: $2995	Interactive software environment under Matlab 4+ for the analysis, design, and display of model-based signal processors	Includes algorithms for simulation, estimation, and identification incorporating linear adaptive and nonlinear systems in state space form, as well as random signals/systems using the Gauss-Markov formulation	—
The Athena Group Inc., Gainesville, FL; 904-371-2567; fax, 904-373-5182				
The Monarch Series Circle No. 255	IBM-type PC: $695	Design and analysis of digital filters, including signal and spectrum display	Integrated menu-driven, high-level program and analysis package for digital signal processors; generates DSP microprocessor codes	Software modules in the Monarch series are available individually

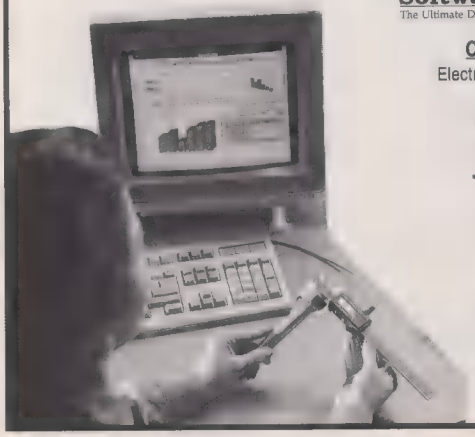
Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
The MathWorks Inc., Natick, MA; 508-653-1415; fax, 508-653-2997; e-mail, info@mathworks.com				
Matlab Image Processing Toolbox Circle No. 256	Macintosh: $895 IBM-type PC: $895 Unix workstations: $1995	Extends Matlab for image and 2-D signal processing	Includes filter design, image filtering and restoration, image enhancement and analysis, 2-D transforms; color, geometric, and morphological operations; requires Matlab Signal Processing Toolbox	Part of the Matlab Technical Computing Environment, which includes application toolboxes for numeric computation and scientific visualization
Matlab Signal Processing Toolbox Circle No. 257	Macintosh: $395 IBM-type PC: $395 Unix workstations: $995	Extends Matlab for signal processing and time-series analysis	Environment for signal analysis, filter design and filtering, spectral analysis, parametric modeling and visualization of time-series data; incorporates new functions for communications, speech processing, and data compression	See above
Matlab Statistics Toolbox Circle No. 258	Macintosh: $395 IBM-type PC: $395 Unix workstations: $995	Extends Matlab for statistical data analysis modeling and simulation	Includes functions for data analysis and interactive graphics; descriptive statistics; probability modeling; regression and random number generation; GUI tools let user interact directly with plots	See above

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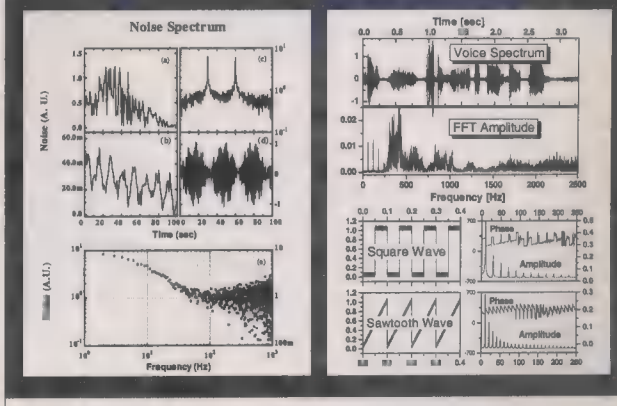
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Circle No. 48

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
The Software Hill, Mountain View, CA; 415-969-4233; fax, 415-967-2795				
RPower 2.2 Circle No. 259	IBM-type PC: $175	Handles numerous statistical computations ranging from curve-fitting to Anova, 3-D graphics, FFT, filter design, matrix operation, and new math/statistics calculations	Extensive regression (curve-fitting) features	—
Ticra Engineering Consultants, Copenhagen, Denmark; (45+33) 124 572; fax, (45+33) 120880; e-mail, ticra@inet.uni-c.dk				
GrasPC Circle No. 260	IBM-type PC: DKK 150 000	General reflector antenna analysis software	Design and analysis of very general single- and dual-reflector antennas; has preprocessor, analysis module, and postprocessor for output of pattern cuts and contour plots	—
TriMetrix Inc., Seattle, WA; 206-527-1801; fax, 206-522-9159				
Axum 4.0 for Windows Circle No. 261	IBM-type PC: $595	Creates publication-quality 2- and 3-D technical graphs and performs data analysis; includes drag-and-drop graphing and OLE 2 support	Graphs are created by selecting data and clicking on a plot button; choose from over 75 2- and 3-D graph types	Axum 3.0 technical graphics and data analysis package for DOS has been available since 1989
Universal Technical Systems Inc., Rockford, IL; 800-435-7887, 815-963-2220; fax, 815-963-8884				
Roark & Young on TK 2.0 Circle No. 262	Macintosh: $395 IBM-type PC: $299 Unix workstations: $995 Other: $299	Computerizes the widely used engineering reference, Roark's Formulas for Stress & Strain, 6th edition; covers the book's entire range of cases	A menu allows the user to easily locate, load, and merge any of the cases; quickly analyzes many design alternatives and plots the results; uses keystroke macros and WYSIWYG report writing	TK Solver
Visual Numerics Inc., Houston, TX; 713-954-6448; fax, 713-781-9260				
IMSL Exponent Graphics 2.1 Circle No. 263	Macintosh: N.A. IBM-type PC: N.A. Unix workstations: $3550 Other: $895+	Interactive graphics library of application-level subroutines for Fortran, C, or X-Windows programmers building graphics applications	Includes over 30 high-level 2- and 3-D plot types common to science and business; has about 300 customizable graph attributes, and support for several high-performance output drivers; reduces development time by up to 95%	—
IMSL Numerical Libraries Circle No. 264	Macintosh: N.A. IBM-type PC: N.A. Unix workstations: $6560 Other: $695+	Libraries of mathematical and statistical subroutines for Fortran or C programmers building numerical analysis applications	Comprises over 900 subroutines for linear systems, interpolation and approximation, differential equations, transforms, nonlinear equations, optimization, random number generation, time series, probability, and regression, and others; reduces development time by up to 95%	—
PV-WAVE Advantage 5.0 Circle No. 265	Macintosh: N.A. IBM-type PC: $995 Unix workstations: $6995 Other: $5495	4GL programming language for developing visual data analysis (VDA) applications	VDA applications let users interactively explore, manipulate, visually analyze, and present large, complex datasets quickly; new features include source code debugger, HDF file support, and improved mapping	Part of the PV-WAVE product family

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
Visual Solutions Inc., Westford, MA; 508-392-0100; fax, 508-692-3102; e-mail, info@vissol.com				
VisSim Circle No. 266	Macintosh: N.A. IBM-type PC: $495+ Unix workstations: $895+ Other: $795	For nonlinear dynamic simulation supporting 80+ math functions and MIMO state space and transfer functions	Programmed through an easy-to-use graphical block diagram; supports data exchange with Matlab, Maple, Mathmatica, Excel; can be extended through user DLLs; display functions include plots, strip charts, plot zooming, and numeric displays and indicators	Add-on products permit frequency domain analysis, code generation, neural networking, real-time data acquisition, discrete-event modeling
Vital Images Inc., Fairfield, IA; 515-472-7726; fax, 515-472-1661				
VoxelView Circle No. 267	Macintosh: $1295	Presents 3-D views of volumes quickly and easily with all internal information preserved	Users may access and control a variety of rendering parameters including opacity, lighting, color and viewpoint, with a point and a click this low-end version of VoxelView combines Vital Images' leading volume rendering technology with ease of use	—

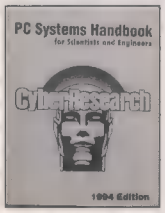
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Circle No. 75

Data analysis and visualization software *(continued)*

Name	Platforms	Package description	Comments	Related packages
VoxelView/E Circle No. 268 (second item)	Unix workstations: $10 000	Entry-level volume visualization and analysis system for manipulating 3-D data without dedicated hardware	Users may adjust a wide range of rendering parameters in an intuitive manner; key features include: measurement capabilities, lighting, rotation, pseudocoloring, opacity control, and multichannel rendering	—
VoxelView/Ultra Circle No. 269	Unix workstations: $10 000+	Takes advantage of Silicon Graphics' advanced graphics to produce dramatically enhanced, ultra high-speed interactive volume rendering and analysis	A powerful volume rendering and analysis system which supports up to 16-bit data and includes comprehensive measurement capabilities, selective control of voxel opacity and other attributes, and multichannel rendering; also gives users the option to embed traditional geometric graphics inside a volume of 3-D data	—
VoxelGeo Circle No. 270	Unix workstations: $30 000+	A visualization-interpretation tool designed for geoscientists; combines interactive volume rendering for 3-D seismic data and geometric modeling	Provides quick access to seismic sections and rapid reconstruction of the 3-D data as a volumetric solid	—
Wavefront Technologies Inc., Santa Barbara, CA; 805-962-8117; fax, 805-963-0410; e-mail, tom@wti.com				
Data Visualizer Circle No. 271	Unix workstations: $6500+	Interactive analysis and presentation package for any 3-D and time-dependent field data	Sophisticated animation capabilities for all tools, cameras, annotation, and data; event playback tools for animation display; flexible viewpoint configuration with multiple orthographic and perspective cameras	Part of company's suite of products for modeling, animation, rendering, scene planning composition, and special effects
WaveMetrics Inc., Portland, OR; 503-620-3001; fax, 503-620-6754; e-mail, wavemetrics@applelink.apple.com				
Igor Pro 2.0 Circle No. 272	Macintosh: $495	For data analysis, automation, and journal-quality graphing	Very fast, handles large data sets, extendable and programmable	Optional Igor XOP Toolkit provides additional extensibility via C modules
Wolfram Research Inc., Champaign, IL; 217-398-0700; fax, 217-398-0747				
Mathematica 2.2 Circle No. 273	Macintosh: $595 IBM-type PC: $595 Unix workstations: $1995	Complete system for data analysis, statistics, visualization, and modeling	Combines a powerful math engine with extensive graphics capabilities, including 2- and 3-D graphics and animations, surface fitting and plotting, vector field, contour, density, and other statistical plots; uses MathLink to connect to C, Fortran, and others, as well as to many commercial applications, like AVS & Spyglass Transform; standard formats include ASCII, binary, DXF, HDF, and Quicktime	Hundreds of mathematical, scientific, and statistical packages are available at no cost through MathSource, the company's electronic resource of Mathematica-related material

Anova = analysis of variance
ASTM = American Society for Testing and Materials
CFD = computational fluid dynamics
CLT = central limiter theorem in statistics
DDE = dynamic data exchange; DSP = digital signal processing;
DLL = dynamic link library;
DXF = Drawing Interchange Format
EIS = executive information system
FFT = fast Fourier transform;
FISH = fluorescence in situ hybridization
4GL = fourth-generation language
GIS = geographic information system
GPIB = general-purpose interface bus
GPS = global positioning system; GUI = graphical user-interface
HDF = Hierarchical Data Format
IJK = parameters describing logical order of points in 3-D space
ILS = Interactive Laboratory System
MIMO = multiple input, multiple output
OLE = object linking and embedding
PICT = Macintosh picture format
RDBMS = relational database management systems
3D-FE = finite elements in 3-D (tetrahedron and eight-mode bricks)
TIFF = tagged image file format; VDA: visual data analysis
WYSIWYG = What You See Is What You Get.

Active data analysis

(Continued from p. 75)

out preprocessing of the data yet without loss of its dynamic range and spatial resolution. For example, the software enables a simultaneous viewing of anatomical and physiological data in the same image, the first data being obtained from magnetic resonance imaging and the second from positron emission tomography.

An ingenious package announced by Advanced Visual Systems provides visual programming tools for application development. Called AVS Express, it enables its users to build applications by connecting icons. The software provides hundreds of objects for visualization, graphics, and graphical user-interface development. Evenhandedly, AVS Express also supports user-written objects using C/C++ and Fortran. It has been embellished, too, with new graphics and plotting options from Uniras Corp., a specialist in graphing and plotting that has been acquired by AVS.



BBN Software Products

[3] A workmap automatically records each step during data analysis. Offered in BBN/Cornerstone software, the workmap shows the sequence as connected icons. Data can be saved and reused without programming.

Other packages wooing users with enhancements include Statistical Sciences Corp.'s S-Plus, DSP Development Corp.'s DADiSP/Filters module, and Intelligent Light's FieldView. The last-named has been made more effective at handling unstructured mesh computational fluid dynamics data, which it can store as hexahedral, tetrahedral, prismatic, and pyramidal elements.

QUESTIONS OF COST. VDA software can cost (as noted) anywhere from a few hundred dollars to $50 000. Typically, the more specific a VDA tool's functions are to a given discipline, the more the tool costs. Developers who cater to niche markets, of course, need higher prices to offset the smaller number of units sold; however, the $10 000–$30 000 price tag of a high-end product such as VoxelView is not too hard to justify for certain applications. For example, in medical research, its use might eventually save lives or millions of dollars in health care expenses.

Most of the leading VDA software is available for Unix and is just now being ported to Macs and PCs. Like other Unix applications, VDA tools for Unix tend to cost more—even though their functionality may be no greater—than their PC brethren. Users may save thousands of dollars, yet get comparable performance, by buying VDA tools for Windows or Windows NT instead of for Unix. AVS, for one, is priced at $6500 on a majority of Unix platforms, whereas the NT version is only $4000. The difference may stem from a perceived reluctance on the part of users to spend $6000 on software for a PC selling for $3000 or so.

But be aware, as developers are quick to point out, that performance in general is better under Unix or Windows NT. For VoxelView, the difference between the Mac and Unix versions is not just a matter of speed and capacity but also involves key features such as handling embedded geometry and other functions unique to Unix. AVS/Express, too, is available only on Windows NT because the package requires an operating system that is capable of multiprocessing.

In some cases, the Windows versions may not be capable of handling the larger problems that Unix can. Again, ask for references and try to estimate the size of the data files to be handled before making a choice. Silicon Graphics Inc.'s version of VoxelView takes full advantage of the SGI architecture that's specifically designed to display and manipulate large 3-D graphics.

Lee Wilkinson, president of Systat Inc. and respected developer of graphics software, summed up the future of VDA best: "The key to the future of Visual Data analysis is complete object orientation. In the future, researchers will not be content with producing high-quality representations of data and scientific graphs or playing with on-screen displays....Instead they are going to want to be able to manipulate any element of a graphical representation of complex data to explore structure in their data and prepare presentations of the results."

According to Wilkinson: "We are beginning to see for the first time the convergence of two major trends in data analysis from the last two decades: the first was sophisticated data display. The second is dynamic exploratory graphs." A concrete example: several visualization packages today allow a continuous rotation of scatter plots in three dimensions to identify data clusters.

ABOUT THE AUTHOR. Ken Kornbluh is vice president of SciTech International Inc., a leading distributor and publisher of scientific and technical software in Chicago.

Below the half-micron mark

Computer-aided design tools are catching up with the shrinking transistor dimensions and channels, high device density, and low power requirements of today's IC designs

Aggressive development within the semiconductor industry keeps electronic products moving on a brisk course forward. Typically, ICs today contain more than three million transistors, plus three to five layers of metal interconnects that supply power and transport signals. Already, silicon circuit features of less than half a micrometer are the technology of choice for memories.

The same device geometry is fast being developed for highly integrated processors, application-specific ICs (ASICs), and other types of logic chips. Projections for the year 2000 include 1Gb dynamic RAMs, 256Mb static RAMs, and ASICs and microprocessors with 40–50 million transistors, frequencies of 400–500 MHz, and pin counts of up to 2000.

The enabling technologies that will permit these ICs to be realized are having to advance, too. Enhanced device structures, interconnects, and circuit design, as well as reduced power, are all vital to success. Consequently, the upcoming generation of computer-aided design (CAD) tools will feature more accurate transistor models and parameter extractors, as well as more efficient timing and power analysis—capabilities that will be pivotal to design, simulation, and diagnosis in all the key technologies.

OUT OF SIGHT. More and more of today's design starts are in what is called the deep submicrometer region, where the smallest feature size is 0.5 μm or less. Four years ago, it was 1 μm, and 10 or 15 years ago, it was 5 μm [Fig. 1]. At today's minuscule dimensions, hitherto negligible second-order effects like leakage currents, threshold voltage variations, hot charge-carriers, and channel punchthrough become a threat. They impede the scaling down of designs and have ramifications for chip voltage, density, speed, oxide thickness, and fabrication and packaging technologies. Although it has been two decades since device engineers began to assess how second-order effects set limits on CMOS design and fabrication technology, it is now imperative to deal with these deep submicrometer issues and to overcome their limiting effects.

Gyanendra Tiwary
EPIC Design Technology Inc.

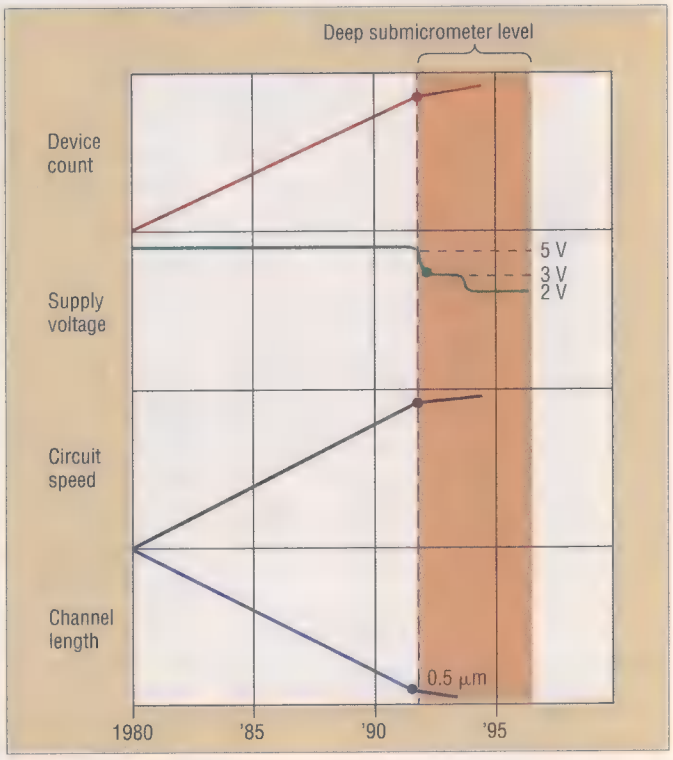
TRANSISTOR SCALING. As devices become smaller, second-order phenomena begin to affect the electrical characteristics of MOS transistors. The scaling rules that allowed a device to be shrunk from, say, 2 micrometers to 1 micrometer do not apply when the same device is further scaled down to deep submicrometer regions. Some of the ill effects are hot charge-carriers, the breakdown of oxide insulation, and increases in transistor source-drain resistance.

An important prerequisite of shrinking device dimensions was the reduction of supply voltages from 5 V to 3.3 V because the higher voltage undermined device reliability. If the dimensions of a MOS transistor are scaled down but its supply voltage is not, hot electrons can pierce its energy barriers and thrust their way into the gate oxide. These charges raise the threshold voltage and depress the drive capability of the device.

In deep submicrometer devices, moreover, the thinner gate oxides result in larger gate capacitance and therefore a larger drain current. The electric field across the gate oxide also goes up and, if unchecked, can lead to runaway currents that short-circuit the gate and the channel.

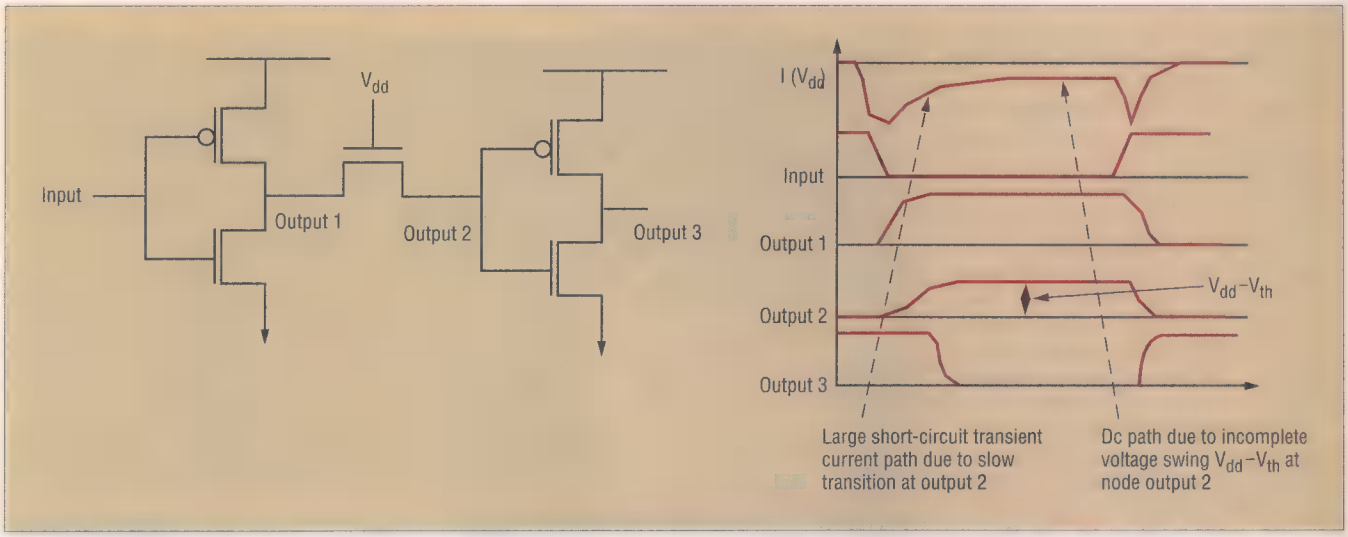
Within the next few years operating voltages will probably fall yet again as feature sizes drop below 0.35 μm. The dwindling supply voltage is particularly welcome to designers of portable electronics because it takes less of a toll on batteries. But, all else being equal, lower voltage also means lower circuit speeds and poorer performance.

Leakage currents have more than one source. When large source-drain voltages confront minimal channel lengths, punchthrough may occur and may leak small but nonnegligible currents just below the silicon surface. Leakage also arises from subthreshold conduction of minority charge-



[1] The 1980s saw steady growth in circuit speed and device count. But the picture has changed dramatically since about 1992, which ushered in the deep-submicrometer regime and the reduction of IC operating voltages.

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[2] Transient currents due to slow switching of circuit nodes and dc paths caused by insufficient voltage are likely sources of power drain.

carriers at the surface, which is at a higher potential than the chip interior. Leakage currents are, in the first place, a needless power drain and also undermine the reliability of dynamic RAMs and other circuits that require refreshing.

At sub-half-micrometer dimensions junction contacts are smaller, increasing parasitic source-drain resistance and so reducing a device's current drive capability. The simplistic assumption that carrier mobility in a MOS transistor is constant—depending largely upon the silicon crystallographic orientation and fabrication processes—has now to be rejected. With smaller channel and oxide geometries the normal electric field in the inversion layer increases, degrading device mobility and requiring a larger electric field across the oxide to establish the desired potential difference.

CAD TECH. Many of today's complex ICs are designed at the register transfer level (RTL) using a hardware description language (HDL) to speed up simulation and testing for functionality. These high levels of abstraction add to the burdens on the CAD tools.

For instance, if a multiplexer is defined at the register transfer level, then the synthesis tool is handed the job of defining its size and drive characteristics. But at the same time, the whole chip's behavior at the circuit level must be available in detail to the designer. It is no longer sufficient to model a worst-delay slice of the design and run Spice-like simulations on it.

Voltage fluctuations, glitches, current spikes, and some second-order effects cannot really be simulated until the transistors interact with each other in the real design. This requirement moves the design away from simple RTL-driven synthesis to a more complex environment in which the behavioral model, the circuit, and its power, timing, and layout are tightly coupled.

With the onset of mobile computing and personal communication systems, the need for smaller form factors and lower weight is driving deep submicrometer designs in two orthogonal directions—maximum speed at minimum power. Even some leading microprocessor manufacturers, who initially released slower, power-hungry versions, quickly adapted to the changing market needs by releasing faster low-power upgrades (for example, Pentium and PowerPC).

OPTIMUM POWER. Much of the power saved by the use of a lower operating voltage is being spent instead on higher transistor counts and clock speeds. As a result, the need to cut back on power has not diminished, but rather intensified. A number of circuit techniques for reducing power are gaining popularity, for instance, sleep modes that power down a circuit when it is not in use. But it is also ■ help to know early on in the design process what the power consumption is and where it is being dissipated. Here, state-of-the-art CAD tools can be of great help.

1. Switching power consumed by various circuits

Circuit	Number of nodes	Number of elements	Switching current, mA	Total current, mA	Switching as percentage of total power
32-bit Manchester adder	582	1 134	3.33	3.92	85%
16-bit parallel multiplier	4 162	9 476	13.3	15.3	87%
Sense amplifier portion of static RAM	475	1 066	12.3	22.6	54%
Microcontroller	14 200	29 956	7.91	16.9	47%
Dynamic RAM	32 676	70 971	14.5	76.5	19%
Signal processor	51 658	103 653	20.1	27.2	74%
Floating-point processor	44 239	106 379	231	307	75%
Static RAM	183 103	522 411	70.2	201	35%

Switching, short circuits, and leakage all make their contribution to the power consumed by an IC. Switching power depends upon the load capacitance, the frequency, and the square of the supply voltage; it is the largest power component of most well-designed ICs. Leakage power is due to subthreshold currents and is largely dependent upon fabrication technology. It is the smallest of the three components, generally being less than 2 percent of the total power consumption.

Short-circuit power is drawn when both n- and p-channel transistors are on at the same time, opening up ■ current path between the power supply and ground [Fig. 2]. For example, slow nodes, as well as nodes that do not quite rise to the level of the supply voltage or fall completely to ground, will cause dc paths in the transistors they are driving [Fig. 3]. For a well-designed circuit, this component should be about 10–15 percent of the total power. But in commercial designs, power drawn

by leakage and short circuits can vary from 15 percent to about 65 percent of the total [see table, p. 85].

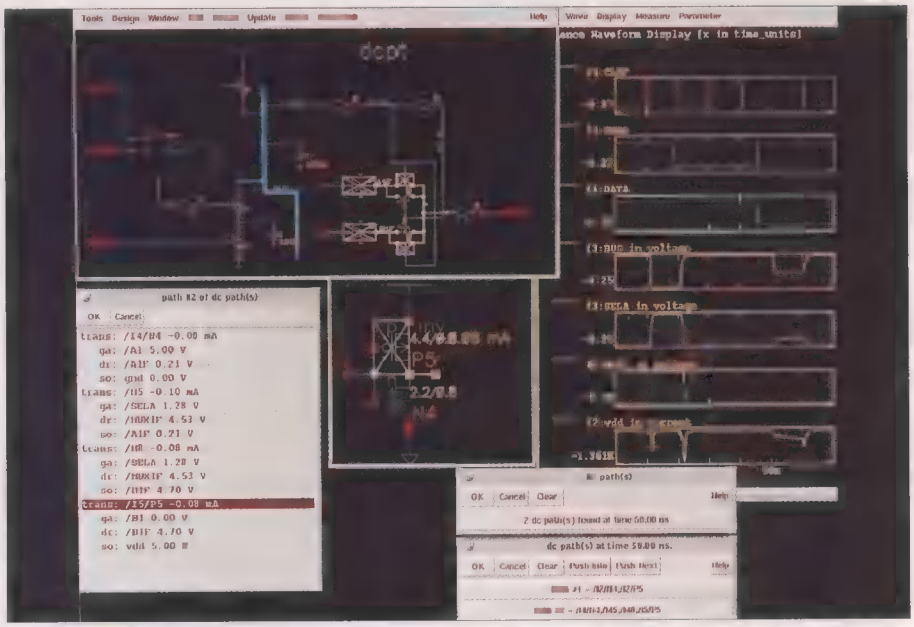
Early versions of power analysis tools relied on toggle counts of cells or other manual estimates. However, because this technique predicts only switching power, it is consistently inaccurate. Nowadays, state-of-the-art power simulation tools not only produce an accurate prediction, but also help the designer diagnose where the power problems are. These tools use event-driven simulations of channel-connected networks and piecewise-linear lookup tables to achieve speeds that are three orders of magnitude faster than Spice simulations while maintaining accuracies within 5 percent of Spice.

The short-circuit power component in many designs is unusually large. Consequently, the effective diagnosis of such current paths may slash power consumption. Power analysis tools should be able to check for static circuit configurations that cause dc paths, as well as to detect nodes that fail to swing to the supply voltage or to ground, as expected.

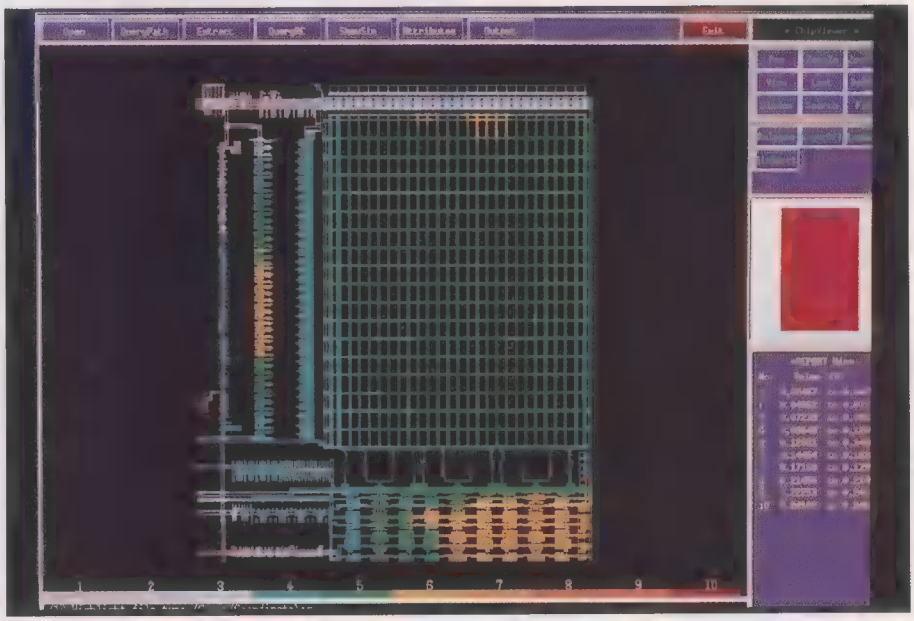
The simulation of the entire IC design at the transistor level in order to compute power accurately—though orders of magnitude faster than Spice—could be improved. It would benefit tremendously from the use of power vectors especially created to simulate the worst-case power of a given design. This technique is under active investigation in companies and universities.

MODEL BEHAVIOR. In an alternative approach, signal and transition probabilities are propagated across a design to model all circuit behavior. Such analysis techniques are still nascent, but if successful, would greatly speed the computation of accurate power consumption. An interesting new concept is transition density (the average number of transitions per second), in which switching probabilities are used to specify typical behavior at the circuit inputs, thus eliminating the need for test patterns.

Along with smaller device geometries come narrower metal lines and larger resistances. As more devices are interconnected, the lines are getting longer, increasing the interconnect resistance still further. The substantial voltage drops that develop across metal power nets cause the circuits to malfunction, especially when the supply voltage is reduced below 3 V. For example, a 1-V drop in a 3-V system would have a much severer impact on circuit functionality than a proportional drop in a 5-V system. So, in deep submicrometer designs, voltage drop analysis is crucial [Fig. 4].



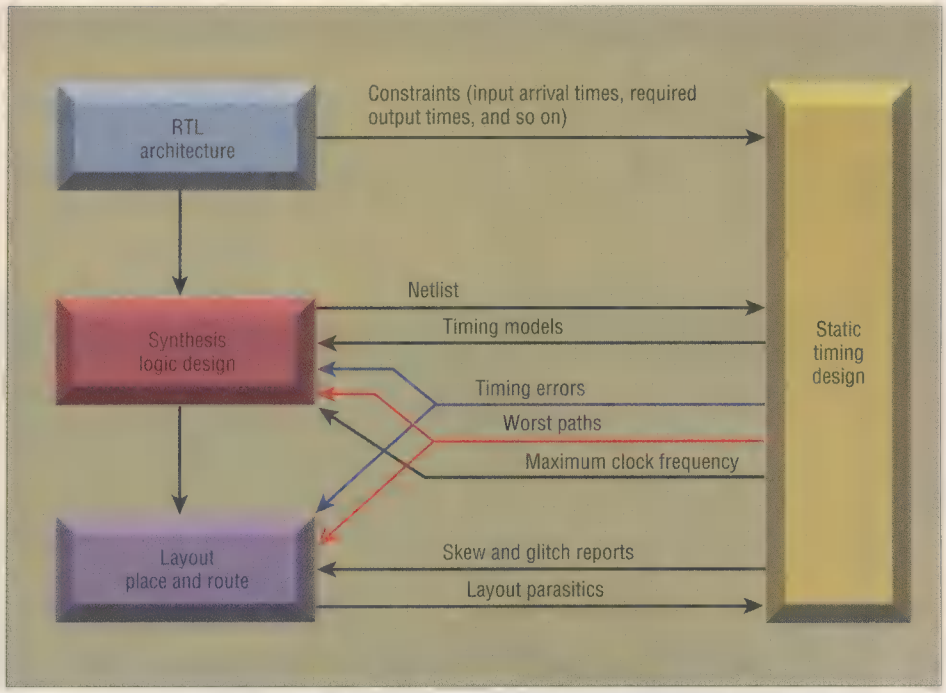
[3] PowerMill, a power management tool from EPIC Design Technology Inc., detects dc paths and other sources of power drain. Here, a glitch on the bus voltage shows an extended period of current consumption as represented by the V_{dd} in current waveform [lower right], caused by the two highlighted paths between the supply voltage and ground.



[4] Voltage drops in a static RAM power net are made apparent by being displayed in different colors for different ranges of values. Color and voltage range keys are at the bottom and the lower right. Power supply inputs are at the left, top and bottom.

One way to perform power-net simulation is to divide a design into two parts—a standard transistor circuit and a power network of extracted supply voltage and ground nets. The transistor current information is computed (assuming a constant supply voltage) and passed on to the power-net simulator. The node voltages and branch currents thus obtained can be used for checking voltage drops. Peak voltage drops can be checked against user-specified thresholds. This gives designers a quick way of identifying problem areas in their designs.

For smaller features, the ability to extract accurate device and interconnect parameters is crucial. Extractors tackle widths, lengths, areas, and perimeters, of course. But in addition, because shrinking device geometries have brought diffusion resistances into the picture, they now pick up source and drain resistances. In deep submicrometer designs, the coupling capacitance between lines and layers is a larger, nonnegligible fraction of the total extracted capacitance and must therefore



[5] Static timing analysis drives logic synthesis and layout of an application-specific IC. The constraints are defined early in the design phase and, together with the logic netlist, are used by the timing analyzer to give timing information to the layout and synthesis tools.

be computed as well.

Clock periods are under 5 ns when clock speeds exceed 200 MHz. So designers need to extract every possible picosecond out of their designs to meet the stringent timing constraints. As chip transistor counts grow into millions, IC simulation is becoming more difficult and taking longer. It would take weeks to run a useful amount of logic simulation on such designs at the gate or transistor level.

Functional verification therefore is done at higher levels of abstraction. Most of the logic verification can take place at the RTL level and, with the help of synthesis, gate-level designs with good functionality can be obtained. But for designs to function at the required speed, accurate static timing analysis is the key to measuring and enhancing performance [Fig. 5].

FINDING THE WORST. Static analysis is a pattern-independent method of finding the paths of a design with the worst delays. Static analyzers find combinations of worst-case paths from all an IC's inputs to all its outputs. They are especially useful for finding critical paths that may not have been exercised by vectors. Also, they are much faster than simulations. For example, they can take less than 20 minutes of computer processing time to complete an exhaustive search of all delay paths in a 50 000-transistor multiplier circuit. More and more designs must now be tuned in this fashion. The static analysis tools can also work at the transistor level, providing the most accurate determination of unwanted effects of deep submicrometer designs.

After analyzing a design unit, a timing delay model (generally called a black box) can be created for use in a higher-level environment. For example, an accurate timing model for an adder could be derived from its transistor-level description and later used as part of an arithmetic and logic unit.

Furthermore, sequential designs can be modeled in this fashion as gray boxes, which retain the timing information of each internal latch while abstracting the timing information of the combinatorial circuits. Such preservation of design abstraction makes it easy for designers to exchange timing information.

Static timing verifiers also come in useful much earlier on, in the planning stages of a design, because they provide timing models for individual design units. During implementation, they can inform circuit designers about any violations of design constraints (timing errors and slack reports).

For example, in an adder block, the output might have to be available X ns after the input becomes available; then any path to the output that is greater than X would be reported as a constraint violation, along with information about different delay points along the path. Sequential designs are also analyzed in the same fashion; with a given clock period and input signal arrival times, the design is checked for all latch-to-latch constraint violations. Correct sequential circuit operation requires that all delay paths lie between a lower and an upper time bound; with the brief clock periods an accurate analysis of such delays has become vital. In the implementation phase, static analysis is very tightly coupled to synthesis and logic design. During post-layout verification it is informative about any negative impact of parasitics. Capacitive coupling between neighboring wires can slow signal paths down or speed them up. Information about clock skews, slow nodes, and static glitches is also invaluable.

Static timing tools, however, are not perfect—yet. The detection and elimination of false paths—those exercised during analysis but never during actual circuit operation—have been a priority for the next generation of static analyzers. Extension of the recognition and analysis of topological information beyond current capabilities is being pursued as well.

Static timing tools now recognize such structures as latches, RAMs, and pass gates; but as designs become more complicated, they will need to recognize larger and more complex structures. This capacity could reduce the number of false paths and in addition cut analysis times. Other enhancements include the availability of timing advisors that suggest solutions to timing problems as part of static analysis. In this role static timing would become more effective in optimization, design repair, and performance tracking.

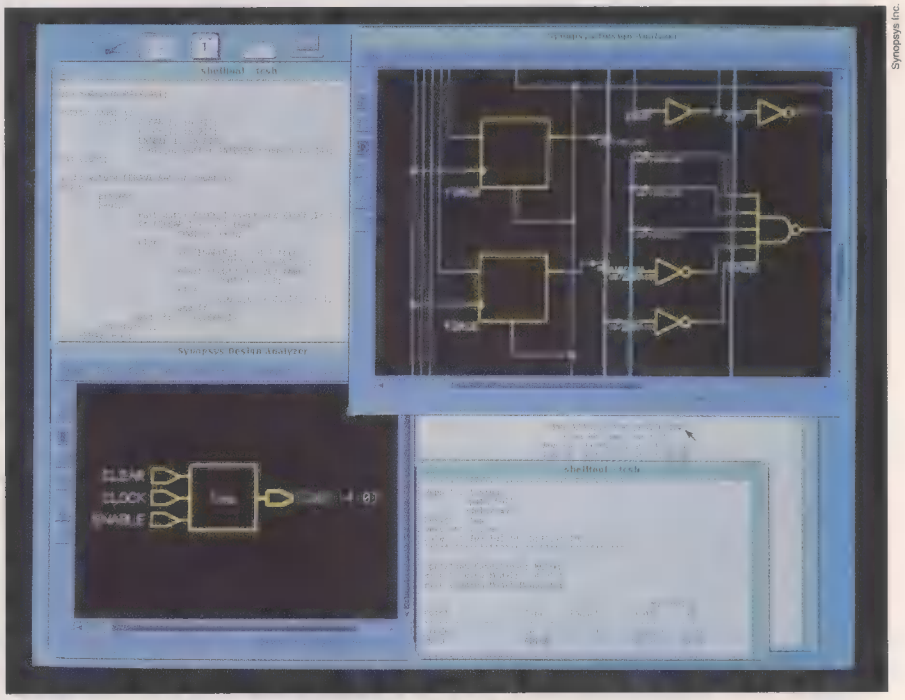
CHANGES NEEDED. To summarize, deep submicrometer designs require a deeper understanding of semiconductor device physics as well as changes in a broad range of disciplines, including fabrication technology, IC design, and CAD tools and methodology. CMOS will continue as the technology of choice, and device performance and circuit density will continue to improve at least down to 0.1-μm levels and maybe even beyond.

CAD technology will focus on low-power concerns and also reliability analysis. With less dependence on simulation, alternatives like static analysis and formal verification will enter the mainstream. A merging of top-down and bottom-up approaches is probable as extraction and interconnect analysis move away from the verification phase into the design phase. Advances in all areas are facilitating these developments, and even though there are still a few hurdles left, there is universal agreement that scientists and engineers will succeed in making the transition to the generation of ultralarge-scale integrated systems and devices. ◆

ABOUT THE AUTHOR. Gyanendra Tiwary is a senior applications engineer at EPIC Design Technology Inc., Santa Clara, Calif. Previously at Intel Corp., he participated in the VLSI design of two generations of reduced– and complex–instruction-set microprocessors. He may be reached by electronic mail at: tiwary@epic.com.

Tools to speed FPGA development

Users of field-programmable gate arrays can now find easy-to-use development tools with powerful verification and optimization capabilities



Synopsys Inc.

[1] A multiwindowed FPGA compiler from Synopsys Inc. eases the implementation of circuit designs as field-programmable gate arrays. Displayed are source file, schematics, and reports from the compiler and Xilinx Inc.'s X-BLOX module generator.

The field-programmable gate array is nearly a decade old. It emerged early on as a leading application-specific IC technology, and today accounts for more design starts in the digital logic market than do traditional, mask-programmed gate arrays. Because of the fast-growing popularity of the programmable type and its increasing complexity, both its manufacturers and the vendors of electronic design automation (EDA) tools are providing the chips with an abundance of development software.

Any tools for developing the field-programmable gate arrays (FPGAs) must be able to implement complex logic designs on an engineer's desktop PC or workstation, while delivering the same ease of design and fast time to market that attract users to FPGAs in the first place [Fig. 1]. The latest tools offer design entry strategies galore, FPGA-specific logic synthesis, greater design portability, and improved design implementation and simulation support, topped off by framework integration. The upshot is more productivity for the system designer.

FPGA design methodology basically consists of three interrelated steps: entry, implementation, and validation [Fig. 2]. Design entry is the process of specifying the logic functions needed for an application. Normally, designers compose schematics with graphical symbols of the logic functions desired and their interconnections. As designs grow in size and complexity, however, text-based entry, in which the logic functions are described in terms of equations and statements much as in writing computer programs, is gaining ground.

Design implementation realizes the desired logic physically in the chosen FPGA architecture. The process is highly automated; it includes mapping the design into the logic resources of the FPGA and determining a placement and internal interconnect scheme that is optimal for those resources.

Validation is the testing of the operation of a completed design with the aid of in-system testing, static timing analysis, and device-, board-, or system-level simulation, among other strategies. The design process is invariably iterative, returning to the design entry phase for correction and optimization.

Fortunately, today's top suppliers of FPGAs support open development environments on PC and workstation platforms, so that generic tools can be used for design entry and validation. In fact, these tools may also be used for logic designs that target technologies other than FPGA. Consequently, FPGA designers can often find familiar tools and techniques among the many schematic editors and logic simulators supplied by vendors like Viewlogic Systems, OrCAD, Mentor Graphics, and Cadence Design Systems.

Place and route tools are different, being unique to each FPGA architecture and usually proprietary products of the FPGA vendor. An exception is NeoCad Inc., Boulder, Colo., a software vendor that provides this kind of tool for several FPGA families from Xilinx, Actel, and AT&T. Generally, design descriptions are passed in a netlist format specific to the FPGA vendor between the third-party EDA tools (schematic editors, say) and an FPGA's own implementation tools. Several FPGA vendors, looking to encourage third-party EDA vendors to develop interfaces to FPGA tools, have established formal alliances with them. By now, well over 100 EDA products support programmable gate-array design.

POINT OF ENTRY. The proliferation of FPGA development tools means that designers may pick and choose among an abundance of styles and types of design entry in order to specify the logic they want. Schematic editors are the preferred tool for design entry. Their use for FPGA design requires both the appropriate library of logic symbols and a translator to convert the schematic into the netlist format used by the FPGA

Bradly K. Fawcett Xilinx Inc.

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vendor's implementation tools. The two items are usually supplied as a package by the FPGA or EDA tool vendor.

FPGA symbol libraries and netlist interfaces exist for many popular schematic editors, including Viewdraw from Viewlogic Systems, SDT from OrCAD Systems, Design Architect from Mentor Graphics, and Composer from Cadence Design Systems. The extensiveness of the libraries reflects the wide variety of digital functions that can be implemented in FPGAs. For example, the schematic library for the Xilinx XC4000 FPGA family contains over 300 macros and primitives, ranging from two-input NAND gates to 16-bit accumulators. Of course, users may define their own macros around already defined primitives and macros.

LOGIC SYNTHESIS. While the structural approach of schematic entry is well suited for describing glue logic (the scraps of interface and control logic found in every system), it is less effective for describing behavioral designs like state machines. Furthermore, as the density and complexity of FPGA-based designs pass the 10 000-gate mark, gate-level schematic entry tools become cumbersome. Hence the increased use of text-based hardware description languages and logic synthesis tools for FPGA design.

Two types of hardware description languages (HDLs) are in use these days for programmable logic. Single-module-level HDLs are employed to describe small modules within a schematic-based hierarchical design; examples are the widely supported Palasm, Data I/O's Abel, and Logical Devices' Cupl design languages, all developed to support the small programmable-logic devices of the late 1970s. System-level HDLs, which support more complex constructs and higher levels of abstraction, emerged in the '80s; the most popular are VHSIC-HDL (VHDL) and Verilog-HDL. System-level HDLs are modular, in that multiple modules constructed using the HDL can be linked into large designs.

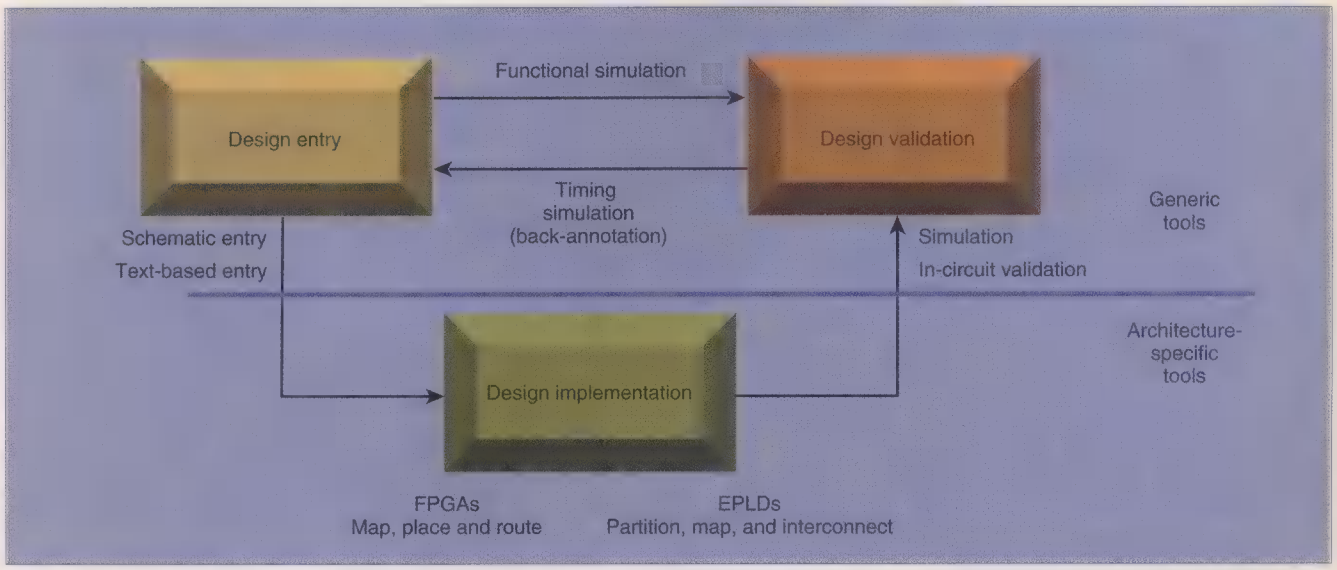
The flexibility of logic synthesis tools and of FPGAs complement one another in the design environment. With HDLs, decisions can be tested early in the design cycle through simulation of the HDL description. Easy-to-make design changes allow experimentation and the exploration of tradeoffs in the architectural design. FPGAs further enhance this design flexibility by allowing the user to implement and test the design at the workbench. The synthesis compilation time is short enough for design decisions to be studied at the gate level of their implementation in the FPGA. Thus, tradeoffs in design features, speed, and size may be investigated with ease.

However, if an HDL-based design entry is to be useful, the synthesis tools must be capable of producing a gate-level design optimized for the target FPGA technology. Early FPGA synthesis tools were modifications of gate-array tools that synthesized the design to a collection of gates without regard to the FPGA architecture. Inefficient implementations were often the result. Newer releases do optimizations for a specific architecture, with vastly improved results. Synthesis tools tailored for FPGA architectures are available from vendors like Synopsys, Viewlogic Systems, Mentor Graphics, Cadence Design Systems, Innovative Synthesis Technologies, and Exemplar Logic.

A synthesis compiler has to map logic functions into an FPGA's architectural resources through inference or through instantiation. Ideally, the compiler should as far as possible infer which resources will be used when, and then automatically map logic and I/O functions into the appropriate FPGA resource. This it does by means of its synthesis and optimization algorithms, starting with generic HDL code. By way of illustration, some FPGA architectures dedicate resources to handling the carry bits in arithmetical operations. If the HDL code describes an adder, the synthesis compiler ideally should be able to map the appropriate logic into these special resources automatically. In other words, the user specifies the logic in a generic manner, and the synthesis compiler takes care of the details of the implementation in the target FPGA architecture. As logic synthesis tools improve, more FPGA resources are coming to be accessible through inference.

INSTANTIATION. Nonetheless, specific FPGA resources can sometimes be accessed only through instantiation; that is, the user explicitly dictates the use of these resources by embedding directives within the HDL code. Indeed, access to the input/output capabilities of FPGAs—I/O registers, say, plus internal pull-ups and slew-rate controls—often must be specified explicitly in the HDL code. Instantiations require that the user be knowledgeable about the FPGA architecture and consequently make that portion of the HDL code specific to that architecture.

Today's synthesis algorithms are efficient at implementing such random logic elements as state machines, look-up tables, and decoders. But the synthesis of data path and arithmetic structures is more problematic, especially if the target FPGA dedicates architectural resources to these functions. Some help is at hand in the form of parameterized module generators provided by the FPGA vendors. These module



[2] The FPGA design methodology basically consists of three steps. For both design entry and design validation, generic tools are available from a number of design automation vendors. Design implementation tools, though, as might be expected, are usually specific to the supplier of the programmable-array IC.

generators accept a generic description of a logic function (maybe "This is an 8-bit binary up-down counter with an asynchronous reset input") and automatically produce an implementation optimized for the target architecture. So, rather than passing a collection of gates to the FPGA-specific back-end tools, the synthesis compiler passes on a higher-level definition of the function and allows the FPGA vendor's device-specific module generator to produce the optimized implementation. The chore of implementing the high-level function is thus shifted from the EDA vendor's synthesis compiler to the FPGA vendor's module generator. Some parameterized module generators are X-BLOX from Xilinx, Scuba from AT&T, and Actgen from Actel. A committee sponsored by the Electronic Industries Association (EIA) is working on an industry standard for these module definitions called the Library of Parameterized Modules. The current 2.0 version is an interim standard created as an adjunct to the electronic design interchange format, EDIF 2.0.

Designs rarely undergo a total metamorphosis but evolve out of previous development efforts. The goal is for new product development to take advantage of the latest devices and technologies while reusing proven portions of earlier designs. A design's reusability in future products is made more probable by the ability to port it to different device architectures.

Design portability is one of the main attractions of high-level design languages. In theory, a design described in an HDL is technology-transparent, relying on synthesis compilers for the job of mapping the logic into whatever device architecture is being used. In reality, technology-independent FPGA design with HDLs is hard; different approaches and coding styles are required for different FPGA architectures, and some FPGA features are accessible only through instantiation. Nonetheless, as FPGA synthesis technology continues to improve, it will become easier to generate device-independent HDL code for FPGA design.

Schematic-based designs also offer a degree of portability. In the case of the Unified Library in the Xilinx development system, all primitives and macros shared by Xilinx device families are consistent in name and appearance. Migration of a design from one family to another requires only a change in the compilation target. Libraries for future Xilinx architectures will use the Unified Library conventions for easier design migration and reuse for future products.

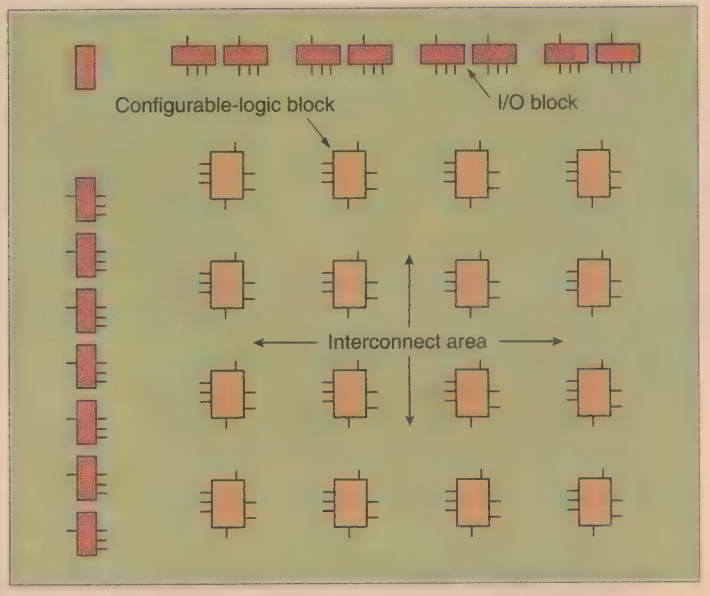
MIX AND MATCH. Most FPGA development systems support the use of hierarchical design techniques, in which top-level drawings

FPGA antecedents and architecture

In the 1970s, digital systems were made up of microprocessor and memory ICs, plus lots of small packages, dubbed glue logic. But as systems became larger and more complex, an economical means was needed for integrating all the glue logic into higher-density chips. Large ICs, though, are affordable only when mass-produced, whereas logic circuits differ from product to product and application to application.

This situation gave rise to the application-specific IC (ASIC) in the late '70s and early '80s. The most popular type of ASIC is the mask-programmed gate array. As the name implies, a gate array is composed of a matrix of logic gates. It is mass produced except for the metal connections that link the gates into logic circuits. It is customized for a particular application by means of masks that determine the gate interconnection scheme. Typically, a gate array user pays a fee—referred to as nonrecurring engineering charges (NRE)—to have the masks created. Prototype devices are fabricated, tested by the customer, and then mass-produced.

But gate arrays have their drawbacks. Lead times for prototype development and production ramp-up delay product introduction. The first prototypes seldom function as well as planned, and iterations can add months to the design cycle. Test programs need to be generated for each device, a task often as tough as the initial design of the part. In short, gate-array development entails considerable risk and expense.



The main elements of an FPGA architecture are an array of logic blocks, a periphery of input/output blocks, and programmable interconnects.

Field-programmable gate arrays (FPGAs), invented in the mid-1980s, eliminate many of the risks and delays of ASIC development. These high-density integrated circuits add user programmability to the flexibility and ease of extension of a gate-array architecture. Like their predecessors, FPGAs contain a matrix of logic elements that can be interconnected in any desired configuration to implement a given application. However, these interconnections are controlled by switches that the user can program with the aid of special equipment. Thus, prototypes can be made quickly, tested, and altered as needed. From the semiconductor vendor's viewpoint, an FPGA is a standard mass-produced product, whereas from the perspective of the system designer, it is a custom device for the end application.

Broadly speaking, FPGAs are constructed out of three types of configurable elements: I/O blocks, logic blocks, and programmable interconnects. I/O blocks interface the external package pins to the internal logic. The array of logic blocks supplies the functional elements for use in the user's logic; logic blocks contain resources for implementing both Boolean logic functions and latching data. Programmable interconnect resources provide the routing paths for connecting the I/O and logic blocks into networks. Several architectures are available today, varying in the size, structure, and number of logic and I/O blocks and in the quantity and connectivity of the routing resources.

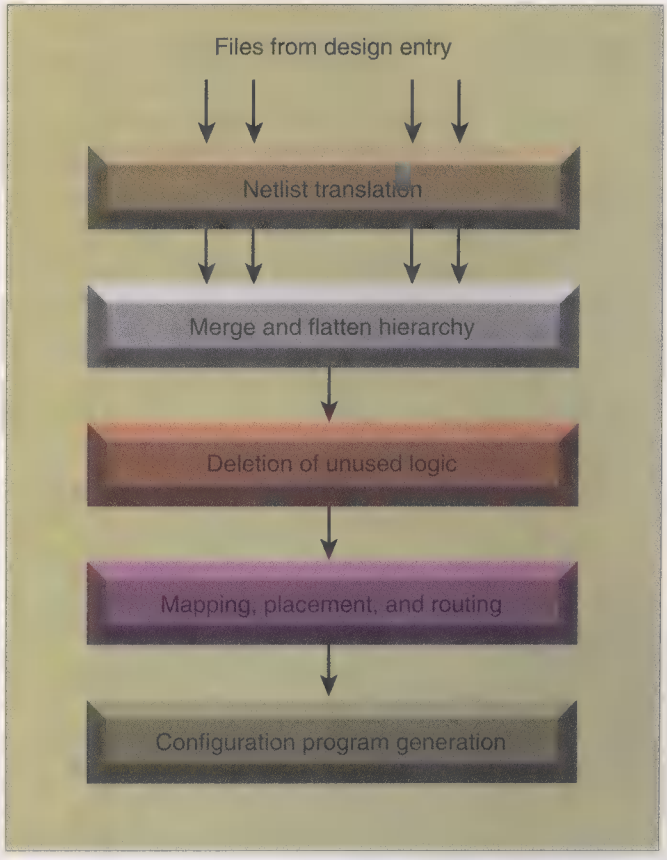
Like microprocessors, FPGAs are program-driven devices. Two programming technologies prevail. Antifuse-based devices can be programmed only once, using special equipment, before the devices are placed on printed-circuit boards, just like programmable ROMs (PROMS). Static-memory–based FPGAs are configured in the target system, much like a programmable microprocessor peripheral; the configuration program is either loaded automatically from external memory on power-up, or is downloaded by a processor during system initialization. Static-RAM–based FPGAs can be programmed and reprogrammed an unlimited number of times, giving rise to the possibility of reconfigurable hardware—that is, logic that can be altered on the fly during system operation.

Admittedly, FPGAs hold less logic and operate at a lower speed than the largest and fastest mask-programmed gate arrays. Still, the rapid advance of FPGA technology is quickly closing the gap. —*B.K.F.*

or descriptions define the major functional blocks, and lower-level descriptions define the logic within each block. The hierarchical approach has several advantages: it helps to structure the design process, eases debugging, and simplifies dividing the design effort among a design team's members. It allows large, complex designs to be handled in smaller pieces. And commonly used functions may be stored in a library as macros for repeated use.

Most FPGA implementation software can combine hierarchical elements specified for multiple design-entry tools, an arrangement that permits the use of the entry method most convenient for each portion of the design. In this type of mixed-mode design entry, designers are free to marry schematic to text and gate-level to behavioral-level design. Mixed-mode design may well come to dominate design entry techniques over the next few years.

IMPLEMENTATION TOOLS. Once entered, the physical implementation of an FPGA design involves several steps [Fig. 3]. First come the jobs of translating the input files into the appropriate netlist format, merging a hierarchical design's elements, then deleting



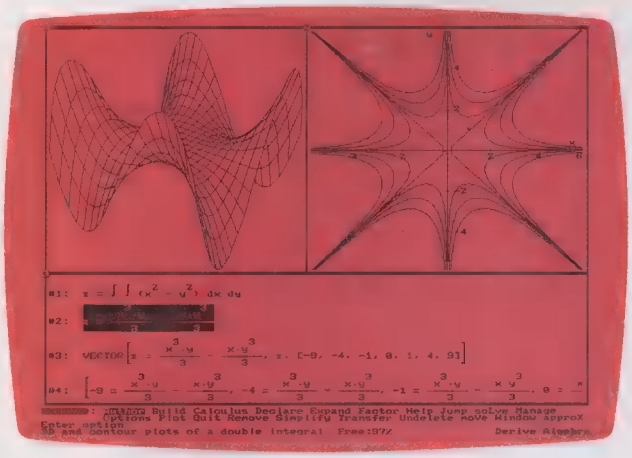
[3] Design implementation begins with the netlists produced during design entry and ends with the generation of the program that configures the FPGA's logic and interconnect switches.

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unused logic, and mapping the design into the FPGA's logic resources. Next come determining an optimal placement for the logic and I/O blocks of the FPGA, selecting the routing resources to interconnect the blocks in the array, and generating the configuration information actually used to program the device. A high degree of automation is applied, so that the entire process is typically triggered by invoking a single design compilation utility.

Implementation begins with the translation and merging of all the hierarchical elements of the design into a single netlist that describes all the design logic. This is followed by automatic logic reduction. This deletion of any unused logic permits liberal use of the macro library without fear of being penalized for failing to utilize some functionality of the macro.

FPGA implementation tools, better known as place and route tools, are then used to map the design into the FPGA architecture and to optimize placement and routing [see "FPGA algorithms," below]. The algorithms and techniques used for this purpose have been improving steadily since the first automated tools for FPGAs were introduced in 1987. In turn, the refined algorithms have influenced the design of new FPGA architectures that are tightly coupled with the implementation tools.

The latest of these algorithms do a timing analysis of the signal paths during the placement and routing of the design. In the past, designers intent on optimizing speed could exert only an indirect influence over automated FPGA layout tools. They had to identify the nets in the design critical to speed and assign an appropriate weight to each one. Then the designers used the weights to influence logic block placement and the net routing order.

HARD TO CONTROL. While net criticality can improve layout results somewhat, its effects are difficult for the user to control. The solution may oscillate because the improvement in the timing of a critical net may cause other connections to become critical, and a second iteration may produce no better a result than the first. Typically, several iterations through the place-and-route implementation software are required, and the success of each one remains uncertain until it is completed and the results are analyzed. Furthermore, net criticality becomes progressively less useful as the number of nets flagged as critical grows progressively larger. In general, weight adjustment methods do not proceed monotonically to a good result.

In fact, the use of net criticality to control layout has distinct limitations because net delays are not a measure of the actual speed of the design. Rather, an application's performance depends on the speeds of entire paths, consisting of sets of interconnects and combinational logic blocks and stretching from a package pin or clocked register to another package pin or clocked register and possibly traversing several nets.

Consequently, new tools such as XACT-Performance from Xilinx and Timing-Wizard from NeoCAD enable their users to specify the performance required along entire paths in an FPGA design. The delays aimed at for each connection are fodder for the placement and routing algorithms, which include routines for analyzing path timing. During placement, estimated logic and routing delays help determine an optimal placement for each logic block in the FPGA.

Once placement has been fixed, an automated router selects interconnects for the blocks. The router, too, is sensitive to delays, so whenever possible, it establishes connections within the limits set. In short,

FPGA algorithms

The algorithms used by the programs for placing and routing FPGAs tend to be quite complex. Some have their roots in the algorithms developed to synthesize and place logic in mask-programmed gate arrays. The fact is that three interdependent, computationally intensive tasks are basic to the implementation of FPGA designs, namely mapping, placement, and routing.

Mapping partitions the design into pieces that fit into the logic and I/O blocks of the target FPGA architecture. A mapping algorithm for FPGAs must distinguish between combinational logic gates and other functions like flip-flops and I/O pads; the latter correspond directly to resources within the FPGA, while the combinational logic must be mapped into the logic blocks.

For example, many FPGAs use memory look-up tables to implement combinational logic functions, and a number of algorithms have been developed to map logic into look-up tables. These algorithms attempt to minimize the total number of look-up tables (to optimize area) or the number of levels of look-up tables (to optimize speed) needed to implement the logic. They differ in the method used to partition the logic, but all involve a matching step that determines whether a given subset of the logic can fit into a single logic block. Some mapping algorithms take routability into account as well.

The placement step takes the defined logic and I/O blocks from the technology mapper and assigns them to physical locations in the target FPGA. Many placement algorithms for mask-programmed gate arrays can also be applied to FPGAs, though with some modifications. In these algorithms, placement is optimized by means of cost functions based on a variety of criteria. For one, the total net length of the resulting block interconnections often corresponds directly to both routability and performance within FPGA architectures. Timing-driven placement tools also incorporate performance needs into the cost functions of the placement algorithms. Most current FPGA placement tools rely on some combination of three algorithmic approaches: mincut, simulated annealing, and general force-directed relaxation (GFDR).

The mincut method begins by dividing the design into two clusters, placing half the blocks on either side of a cut line. Then elements are swapped, being moved across the cut line to reduce cost; the main factor in the cost function is the number of interconnects crossing the cut line in order to keep connected blocks close together. The algorithm goes on dividing each cluster into smaller clusters until each represents one logic block.

Simulated annealing is a more complex algorithm, modeled after the crystallization of a solid from its molten form. The elements of a randomly chosen placement are swapped. If the new placement results in a lower overall cost, it is accepted. If it results in a higher cost, there is still a finite probability of the new move's being accepted; the probability of acceptance of a bad move is proportional to the "temperature" during the "annealing process." Accepting occasional bad swaps prevents the algorithm from settling into a local minimum when a more nearly optimal solution may exist. Temperatures are high at the beginning of the process, and are gradually lowered.

In the GFDR algorithm, nets between blocks are modeled like physical springs, whose strength is proportional to the criticality of the net and other cost considerations. Placement improvement involves swapping the locations of two blocks or cycling the locations of several blocks. The prime candidate destination for a given block is the "center of gravity" of those blocks connected to it.

Placement over and done with, at least for the time being, the routing paths for the interconnections are chosen. Most FPGAs use some variation of a maze router, which looks for the shortest path between two or more points; routing is along vertical and horizontal axes only, and as the number of routing paths through a given channel between blocks is limited, occasional detours are inevitable.

Most FPGA routers include rip-up and retry capability, for removing an already established route and rerouting it to make room for another signal. Timing-driven routers calculate interconnect delays as they progress, and so include performance information in the decision process.

Run times ranging from several minutes to several hours can be expected, depending on the size of the FPGA device and the complexity of the design. High-end workstations are recommended for designs requiring more than 10 000 gates. —*B.K.F.*

the designer can enter specifications that reflect the actual performance required for the design, and the implementation programs will use them to guide the placement and routing process.

Depending on how demanding an application is, the user may opt for a greater or lesser degree of control over its implementation. For example, directives may be issued to control the mapping of selected logic blocks or the assignment of I/O signals to particular pin locations. In addition, ■ selected logic block (or blocks) may have its placement restricted to a certain user-defined region within the array; the placement algorithms then select the best location for the block anywhere within that region. In effect, the user is enabled to perform the floor-planning basic to control the device's overall structure.

Highly structured designs can benefit greatly from the floor-planning techniques already familiar to designers of large gate arrays. Currently in development are dedicated floor-planning tools, with which the designer manipulates a graphical image of a design's functional blocks, placing them on a model of the FPGA device.

ONE STEP AT A TIME. Incremental design support is another useful feature of the latest FPGA implementation tools. It helps out when minor changes are needed near the end of a design cycle, whether to fix a bug or respond to a change in specifications. It is also useful for the implementation of a large, complex system, a job that can be simplified by being tackled one small portion at a time.

Incremental design techniques employ a proven implementation as ■ guide to the placement and routing of a new version of a design. Where the two versions match, the newer design duplicates the old one, preserving its placement and routing and hence its timing characteristics. Where they do not, use of the guide option leaves only a small piece to be altered, re-implemented, and re-tested—all in a matter of minutes.

This same option, in concert with placement constraints, makes possible the incremental construction of ■ large design. Just one small portion of a design could be implemented within an FPGA, perhaps with regional constraints on placement to confine it to one segment of the logic array. Then more logic is added to the design, as indicated by the previous implementation. The earlier logic maintains its original placement and routing as the new logic is implemented and then tested. Other modules are added in ■ similar manner till the design is complete.

After the design elements have been fully placed and routed, the final step is to generate the binary configuration program. It is downloaded into the FPGA to implement the specified logic. The configuration program generator is analogous to a microprocessor's assembler.

The validation of FPGA designs is usually a matter of combining in-circuit testing and software simulation. The user-programmable nature of the gate array means that circuit designs can be tested straightaway in the target application. But as designs increase in density and in complexity, more circuit paths may suffer from timing problems, and timing simulation becomes an invaluable tool.

To support timing simulation, FPGA implementation tools include calculators that determine the post-layout timing of implemented designs, including the actual delays of routing paths. This information is annotated into gate-level libraries for simulators like Viewlogic System's Viewsim, OrCAD's VST, and Mentor Graphics' Quicksim. A good many simulation interfaces support back annotation (the mapping of timing information back into the signal names and symbols of the original schematic) to ease the debugging effort.

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FPGA design flow in detail

The creation of an FPGA design using a schematic editor involves entering the design and testing its functionality, implementing and testing its performance, and programming it. Usually, report files are generated at each step, along with any error or warning messages necessary.

First, then, the symbol library for the target FPGA architecture is used to create the schematic. Some symbols have attributes, which are assigned on the schematic. For example, an output buffer may be programmed for a fast or slow slew rate, or an output signal may be assigned to a particular pin location. It is generally a good idea for all symbols and nets on a schematic to be assigned symbolic names. The subsequent preservation of component and net names by the assorted development tools will ease the debugging effort.

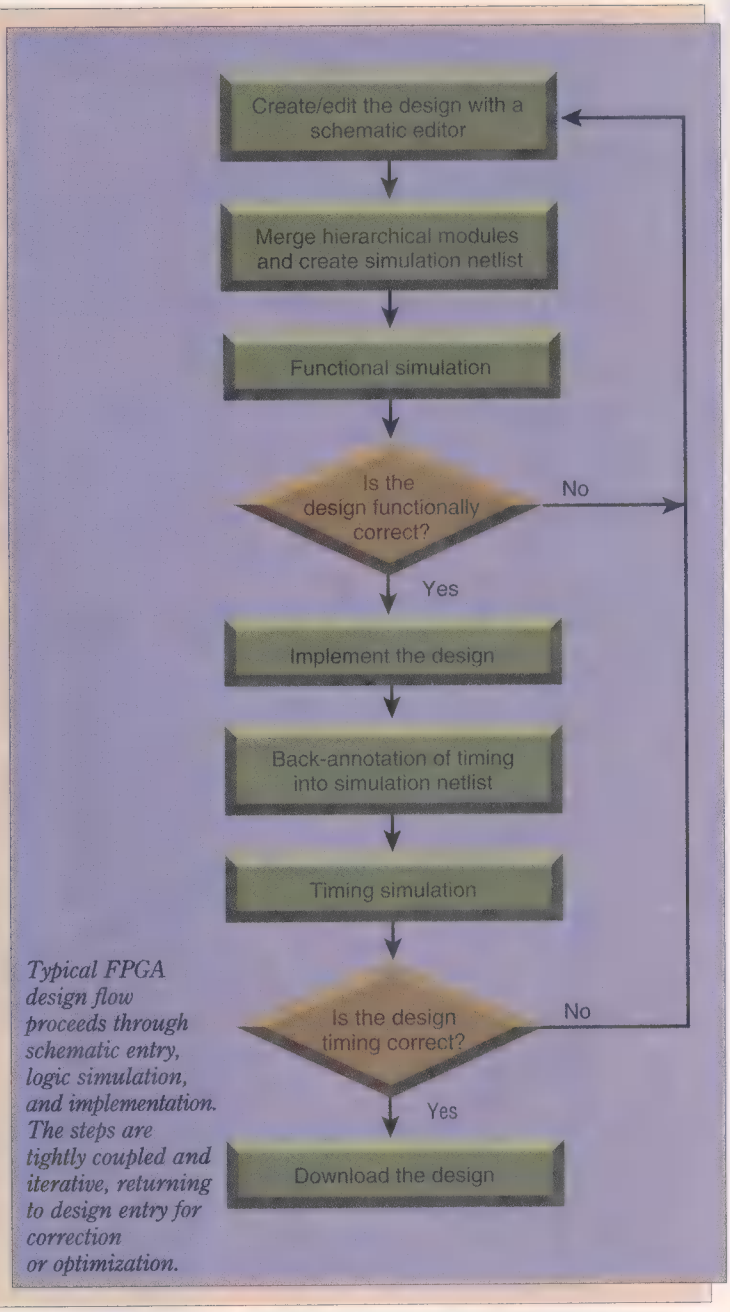
Once a design has been entered, its functionality can be tested by being simulated in software—an effective means of identifying logic errors in a design before it is implemented in the FPGA. Because the design elements have not yet been placed and routed, no timing information for the design is available, so the simulator uses unit delays instead. Most often, a utility program is invoked to run the translation routines that create the netlist in a format compatible with the simulator. In more detail, the utility translates the netlists from the schematic editor into the FPGA vendor's netlist format, merges files from the hierarchical blocks that constitute the design, and translates the resulting flattened netlist into the netlist format required by the simulator.

As for implementation, placed and routed FPGA designs can be generated automatically by executing a compilation utility. This software retrieves the design's input files and from them creates the FPGA configuration program. The steps here are: translating the input files to the FPGA's netlist format, merging the elements of a hierarchical design, deleting unused logic, mapping the design into the FPGA's logic resources, placing and routing the logic and I/O blocks, and generating the configuration program that is loaded into the FPGA.

Next, timing simulation verifies the design's functionality by inserting worst-case delay information in a fully implemented FPGA design file. A utility program reads the routed FPGA design file and automatically creates the files and directories needed for the timing simulation. Because the timing delay information for the design is passed through all the translation programs, actual worst-case delay times are used during simulation. This reduces the need for hardware debugging as well as determining if the design works under worst-case conditions.

Finally, the user-programmable nature of FPGAs allows designs to be tested immediately in the target application. Array chips based on static RAMs are usually supported by a cable for downloading configuration files from a PC or workstation to an FPGA residing in the target system. One-time–programmable antifuse-based FPGAs must pass through a dedicated device programmer before being inserted into the target system.

—*B.K.F.*



Typical FPGA design flow proceeds through schematic entry, logic simulation, and implementation. The steps are tightly coupled and iterative, returning to design entry for correction or optimization.

plexity, more and more users are employing board- and system-level simulation that spans multiple types of devices—this in addition to simulating each FPGA on its own. Most libraries provided by FPGA vendors contain enough information to support board-level simulation. Alternatively, FPGA behavioral models, such as the SmartModel library from Logic Modeling, can be used with a variety of third-party simulators to support system-level verification.

Static timing analysis is catching on as a technique for verifying synchronous designs. Static timing analyzers examine a design's logic and timing to calculate signal path performance, identify possible race conditions, and detect set-up-and-hold-time violations. Unlike simulators, timing analyzers do not require that the user generate any input stimulus patterns or test vectors. However, the majority of users apply static timing analysis only to fully synchronous designs, because it is a difficult technique to apply accurately to asynchronous circuits.

FINE FRAMEWORKS. An FPGA development environment typically integrates generic design tools and architecture-specific implementation tools, hopefully in an easy-to-use manner. Most FPGA vendors provide their own design management software.

The Xilinx Design Manager, for instance, takes various implementation tools and utility programs and organizes them into pull-down menus arranged to reflect the user's normal design flow. These tools can be hooked into other frameworks, but, at some point, the user goes from the host EDA vendor's environment into the Xilinx tool set.

Encouragingly, however, some tool sets are now available that are more tightly integrated. Viewlogic Systems, Mentor Graphics, Cadence Design Systems, and Data I/O are among the EDA vendors that can provide full front-to-back design capabilities in kit form by melding an FPGA vendor's implementation tools into their own frameworks.

ABOUT THE AUTHOR. In his seven years with Xilinx Inc., Bradly K. Fawcett has held a variety of applications engineering, technical marketing, and technical training positions, and is currently applications engineering manager. A veteran of 19 years in the industry, Fawcett has prior marketing and design engineering experience with Zilog Inc., Amdahl Inc., and Burroughs Corp.

To probe further

MATH TOOLS. A good survey of numerical software is given in *Sources and Development of Mathematical Software,* edited by Wayne R. Cowell (Prentice Hall, 1984, Englewood Cliffs, N.J.). For the many numerical routines available over Internet at Netlib, see "Internet and Netlib," p. 41. Obtaining routines in Netlib is described by Jack T. Dongarra and Eric Grosse in "Distribution of Mathematical Software via Electronic Mail" in the May 1987 *Communications of the ACM,* Vol. 30, pp. 403–07. For information on symbolic analysis, *Computer Algebra* by J.H. Davenport et al. (Academic Press, 1988) and *Elements of Algebra and Algebraic Computing* by J.D. Lipson (Benjamin/Cummings, 1981) are excellent.

VISUALIZATION. The proceedings of the annual IEEE visualization conferences, held from 1990 on, supply basic reference material for trends in scientific visualization. The state of the art in the closely related field of computer graphics is on record in the proceedings of the annual Siggraph conferences held by the Association for Computing Machinery (ACM) and the videotapes it produces.

Texts include *Visualization In Scientific Computing* (IEEE Computer Society Press, 1990) and *Computer Visualization* (Solomon Press/CRC, 1994). The first is a collection of early publications edited by G. Nielson and others. The second is a reference text edited by Richard S. Gallagher, covering topics such as scalar and multivariate field display, volume rendering, animation, and implementation issues.

A good overview of scalar, vector, and tensor display techniques for three-dimensional fields can be found in the following papers: "Marching Cubes—a High-Resolution 3-D Surface Construction Algorithm" by William Lorensen and Harvey Cline (*Siggraph '87 Proceedings,* July 1987, pp. 163–69); "The Stream Polygon: a Technique for 3-D Vector Field Visualization" by William Schroeder, C.R. Volpe, and William Lorensen (*IEEE Visualization '91 Proceedings,* pp. 126–32), and "Visualizing Second-Order Tensor Fields with Hyperstreamlines" by Thierry Delmarcelle and Lambertus Hesselink (*IEEE Computer Graphics and Applications,* Vol. 13, no. 4, 1993, pp. 25–33).

Arie Kaufman's *Volume Visualization* is a basic collection of articles and research papers on continuum volume field display (IEEE Computer Society Press, 1990). His article "Volume Graphics," coauthored with Daniel Cohen and Roni Yagel, discusses volume fields as a basic approach for future graphics (*Computer,* July 1993, pp. 51–64).

Recent *IEEE Spectrum* articles on aspects of visualization include "A 'room' with a 'view,' " by Tom DeFanti, Dan Sandin, and Carolina Cruz-Neira, in an October 1993 special report on virtual reality [pp. 30-33] and "Seeing data in action" by Ken Kornbluh in the November 1993 issue [pp. 60–75].

ACTIVE DATA ANALYSIS. Computer graphics software and hardware, animation methodology, and more are regularly covered in *IEEE Computer Graphics and Applications Magazine.* Techniques for and applications of scientific visualization are discussed in *Visualization in Scientific Computing,* edited by Gregory M. Neilson, Bruce Shriver, and Lawrence Rosenblum (IEEE Computer Society Press, 1990).

SUBMICROMETER DEVICES. Low-power design is summarized very well in "Low Power CMOS Digital Design," by Anantha P. Chandrakashan and others, in the *IEEE Journal of Solid State Circuits,* April 1992. The *Proceedings of the 1994 International Workshop on Low Power Design* (held in Napa, Calif., in April 1994 and sponsored by the ACM's Special Interest Group on Design Automation [ACM-Sigda] and IEEE's Circuits and Systems Society) provides comprehensive coverage of most low-power design activities within the industry.

A brief but thorough introduction to submicrometer technology is to be found in the first two chapters of *Circuits, Interconnections and Packaging for VLSI* by H.B. Bakoglu (Addison-Wesley, 1990).

FPGA DESIGN. Several good texts discuss field-programmable array (FPGA) architectures and the algorithms used in FPGA implementation tools, including *Field-Programmable Gate Arrays* by Stephen D. Brown and others and *Field-Programmable Gate Array Technology,* edited by S. Trimberger (published in 1992 and 1994 respectively by Kluwer Academic Publishers, 1994), as well as *Digital Design Using Field Programmable Gate Arrays* by Pak K. Chan and Samiha Mourad (PTR Prentice Hall, 1994).

The ACM International Workshop on Field Programmable Gate Arrays is sponsored by ACM-Sigda, which is based in New York City; the second annual workshop was held in February 1994, in Berkeley, Calif. Kingston, Ontario, was the site of the second annual Canadian Workshop on Field Programmable Gate Arrays, organized by Canadian Microelectronics Corp. in June 1994.

The IEEE sponsors several annual conferences on ASIC technology that often include papers on FPGA tools, including EuroASIC (part of the European Design and Test Conference), the Design Automation Conference, and the IEEE International ASIC Conference and Exhibit. Their proceedings are available from the IEEE Computer Society Press.

The February 1994 issue of *ASIC & EDA* magazine includes a report on the programmable logic tool market. A comprehensive chart accompanying the article lists FPGA development tool vendors and summarizes their product offerings.

Lastly, extensive product information is available from the FPGA and EDA tool vendors. ◆

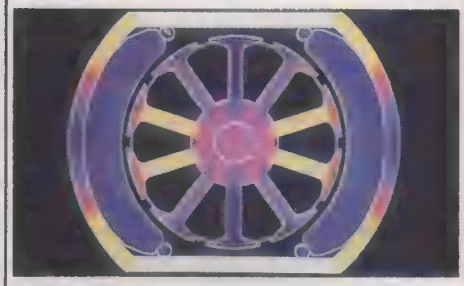
Acknowledgments

In preparing this special focus report, *IEEE Spectrum* drew on many sources. We are specially indebted to the individuals listed below for their advice and guidance, although their identification with the report should not be construed as their endorsement of any opinions or products covered in these pages, nor of the accuracy of the statements made in the articles.

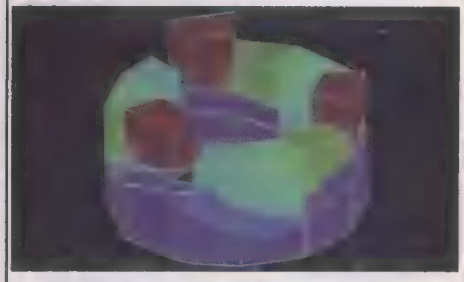
Advisors for this report included Kenneth H. Carpenter and Michael S. P. Lucas, professors in the department of electrical and computer engineering, Kansas State University, Manhattan; Thomas A. DeFanti, director of the Electronic Visualization Laboratory, University of Illinois, Chicago; Brian Evans, postdoctoral researcher in the department of electrical engineering and computer science, University of California at Berkeley; Kenneth R. Foster, associate professor in the bioengineering department of the University of Pennsylvania in Philadelphia; Mark Mirotznik, assistant professor in the electrical engineering department of the Catholic University of America, Washington, D.C.; Ayowale B. Ogunye, senior research engineer at Dow Chemical Co., Midland, Mich.; A. Ravishankar Rao, of IBM Corp.'s Thomas J. Watson Research Center, Yorktown Heights, N.Y.; Rob Rutenbar, associate professor at Carnegie Mellon University, Pittsburgh; and Daniel G. Swanson, staff scientist at Watkins-Johnson Co., Palo Alto, Calif. ◆

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Circle No. 77

Taking charge of your promotion

How to steer your career toward the goals you want is outlined in this article, the first in a series on advancing your career that deals with topics they don't teach in school



Rob Dunleavy

Are you in control of your career? Many engineers who think they are, in fact are not. They go to work each day assuming that the big raise and promotion are just around the corner. When nothing happens, they're bewildered.

"I deserved it," they complain. "Why does everyone else get promoted? Why am I still waiting?" The answer is simple: they left their promotion up to chance.

Never leave your promotion up to chance. Controlling your career takes planning, hard work, and the ability to turn circumstances to your advantage. Knowing everything it takes to get promoted in your company and constantly working toward that goal is essential to steady advancement. It will certainly mean faster raises and promotions.

Several factors could be limiting your career growth. Key among them are obsolescence, your personality, your level of education, your supervisor, and maybe even the structure of your company or department.

Ask yourself these questions:

- Were your last pay increase and/or your performance rating lower than you expected?
- Do you feel your hard work often goes unrewarded? Does it seem other people are always getting awards or recognition?
- Have you ever been passed over for a promotion and really don't understand why?
- Are you stuck in a dead-end, thankless job?

The more times you've said "yes," the stronger the indication that you are not in control. A "yes" to the final question merely emphasizes this fact. Waiting to discuss your career plans until your job review with your supervisor leaves it much too late.

John A. Hoschette — Loral Infrared and Imaging Systems

Adapted from Chapters 1 and 2 of Career Advancement and Survival for Engineers *by John A. Hoschette (with permission, John Wiley & Sons Inc. [800-225-5945], 1994, 200 pp., $39.95 cloth, $15.95 paper).*

Career planning and preparation should take place long before you enter your supervisor's office. You must be aware of the dynamics within your company and use them to your benefit. Convincing the supervisor that you deserve a promotion should be the last thing on your agenda, not the first.

Do you need to be in control at all times? Yes! Yes! Yes! If you are not planning the next step in your career, you are out of control. Worse yet, you are letting others control your advancement. Failing to take charge and plan is not the way to a successful career. To succeed you must know what to do, when and how—in short, how to play the game.

KNOW THE RULES. Your fellow employees may have some rules of thumb to suggest: flatter the boss; it's who you know that counts; work overtime and be a hero, and so on. But, these are guesses at best. To get ahead you must know how the promotion game is played at your company and how to score points.

Let's assume you are the key player of the team—everyone is counting on you. It is the second period of the third quarter, the teams have lined up, and the goalie is calling the play. On the previous play the putt was good for 3 points, but the right wing was penalized when 5th base was stolen. They have the option to bowl for a strike or fast pitch for a slam dunk. What do you recommend?

Everything sounds somewhat familiar, right? But as you really don't know the rules or how points are scored, your chances of making the right decisions are small.

Moving up in your career is similar. You are the key player in this game of doing a good job, flattering your supervisor, and working hard. But will all these things lead to advancement? More than likely, they won't.

The bottom line is this: if you don't understand how your company plays the career advancement game, you cannot expect to get ahead. So learn the game and how your company keeps score, and start calling the plays that will score your career advancement. There's no time like the present. Remember, your next promotion may be a year or more away from the time you start planning.

GETTING STARTED. As the first step, determine your company's structure. If necessary, sit down with your supervisor or someone senior in the company and map it out.

In point of fact, you should be aware of several structures. Probably the most familiar is the hierarchy of the engineering levels in the company. But just as important is the task and reporting structure, of which there are generally two types. One is product oriented and the other is function oriented. Within these structures, hidden career barriers often exist of which you must be aware.

The career path at most engineering companies begins with nonsupervisory engineers at the bottom [Fig. 1]. As many as four or five engineering levels may intervene before the staff or supervisory level is reached.

In the lower engineering levels [E1 and E2 of Fig. 1], you are expected to be a good team player and learn from your seniors—

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the old pros. You may be able to do your assignments in as little as a day or two, usually by yourself or with the help of another person. As you rise in the middle levels [senior and principal engineer], you start to lead small teams of two or three people to accomplish specific objectives. Assignments may last weeks or months. You are responsible primarily for technical work.

In the upper engineering levels [E4 and E5 of Fig. 1], you direct large teams of engineers with various backgrounds. Objectives are seldom well defined, and it is up to you to plan things out. Along with providing the team's technical direction, you must maintain schedule and cost controls. You need good interpersonal skills to ensure that work is being done by other people rather than by yourself.

ARE YOU A TECHIE? At the staff level, several career choices must be made. Typically there are four paths upward. At larger companies, the very technically oriented ladder is the fellows ladder [Fig. 1, far left]. In less formal organizations, they are the "senior scientist" types. They are usually Ph.D.s often recognized for their speciality both in and out of the company. The stereotype is of a silver-haired figure in a messy office hung with patents, plaques, and awards.

Usually they are interested in only one thing—science! They may deal only with technical issues and avoid managerial or cost issues. Learn who they are in your company. They know thousands of technical shortcuts and can usually get you out of a jam if you don't understand something.

A word of caution, though. Fellows have seen practically everything and are thorough. Don't shoot from the hip around them. Be precise. Associating with fellows can accelerate your career if they are well respected—or dead-end it quickly if they are labeled as eccentric professors.

STAFF LADDER. Another ladder is staff engineering [second from left in Fig. 1]. These people mostly have a master's degree and deal with putting systems together. The staff engineers work with system-type problems such as the overall performance of a product. In the case of a car, this may include aerodynamic shaping, motor efficiency, weight, and speed, whereas a fellow may deal only with one specialized characteristic of the product—for example, the performance of the spark plug.

Staff engineers, like fellows, concentrate mainly on technical issues but also often advise management on schedule and cost issues as well as technical matters. Highly analytical, they are responsible for how things are coming together technically. They generally have the best computers in the group. Their office walls sport collections of flow charts and graphs showing tradeoff studies. If you try to get an answer out of them, they invariably qualify it with the phrase "That depends upon...."

Another word of warning. Staff engineers are big picture people, who want to know what all the causes and effects are. So if you go to them with only the small picture, they may quickly tag you as not understanding the problem and incompetent—not what you want your boss to hear. As with the fellows, be prepared if you plan on interfacing with them.

RUNNING A PROGRAM. A third career ladder is program management. Typically, these managers run programs or projects and are responsible for cost and schedule performance, not the technical side. They organize teams of engineers to get the job done on time at the cost they quoted. Generally, they are the primary interface with the customer.

The program managers control the funding for programs and have little to do with personnel and salary administration (raises). Quite the reverse—they discount personnel problems and often the company will pay them a bonus if the project is brought in on time and within cost.

A third cautionary word: program managers are not interested in excuses but in getting the job done, so you may find that they can be abrasive at times. They can do a lot to help you get your raise, or prevent it.

Last but not least, there is the management career ladder. Profits and personnel are these people's responsibility. They hand out the raises, promotions, and demotions. They make most of their decisions based on profitability. Their philosophy is "if we can make money, let's do it; if not, stop doing it!" I've seen great engineering projects suddenly halted because they were not making money for the company. This is usually the tallest ladder of the company with the highest salaries.

As you move up the ranks, you will have to decide which ladder is right for you. If you like technical work, prepare yourself by taking more technical courses. If you prefer management, take more business courses.

Also, since each successive level becomes more demanding, you must decide what level is right for you. If your family is important to you, being vice president may not be for you, as the job usually infringes on family life. In short, how high you decide to climb is strictly a personal decision as to how much responsibility you care to accept.

Nonetheless, you can have a very successful career without becoming president of the company. Your success need not be measured in terms of titles, power, and profits. If you remain technical, it can be measured in terms of breakthroughs, papers published, patents, and technical awards.

The crucial point here is that you must define what success means to you, whether it is getting to the senior level or becoming a supervisor or simply doing the best possi-



[1] Your career may move along engineering or business paths with varying mixes of each.

ble job. Not everyone wants to become vice president of the company. But everyone should define what success means to them.

FRONT-LINE SUPERVISOR. Which level is the toughest? In my opinion, it is the first-line supervisor. All the great ideas generated by the president of the company on how to run the organization must be implemented at this level. The first-line supervisor follows policies on vacations, health care, drug testing, expense reports, employee training, security, raises and promotions, and project successes and failures, personnel problems, and department budgeting, to name just a few.

Put simply, first-line supervisors are caught in a vise between all of the directives from management above and all of the employee problems below. They must do everything and it all has to be done now. They are frequently so overloaded with work that a good many quit and return to the technical ladder or else end up divorced. It is an extremely stressful and time-consuming position.

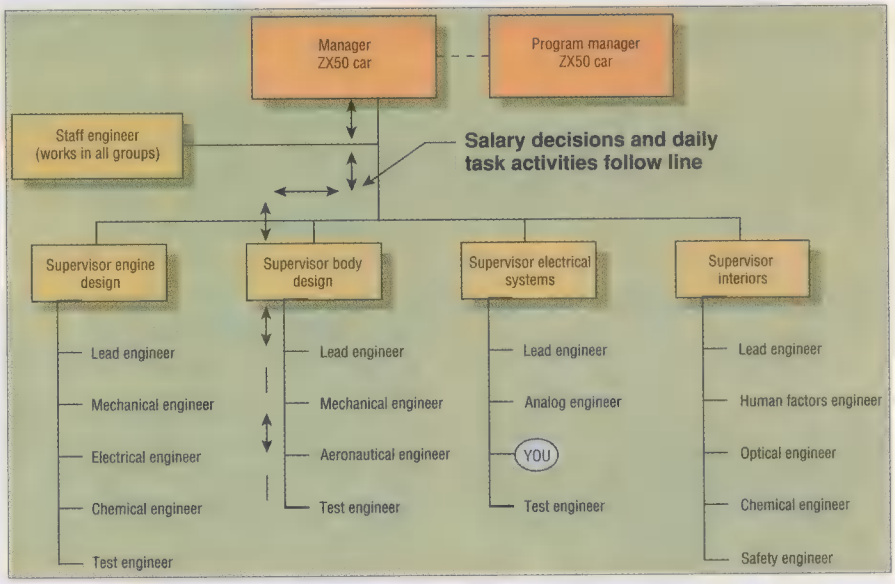
Make your supervisor your friend, not your enemy. The last thing they need is you running into their office whenever there's a problem. When you go in to talk to your supervisor, remember they probably have a thousand concerns on their mind.

Depending on the company, of course, between the lowest level and the top there can be as many as 12 levels, though recent downsizing is paring such numbers down. If you got a promotion every three years (and this is considered fast), it would take you 36 years. Clearly, every promotion must count. But at a major corporation, the president is usually 1 of, maybe, 40 000 people. At those odds, you are unlikely to become president.

At most companies, top-level executives are expected to have a broad background and understand all aspects of the business. For this reason, most of them will have worked on a variety of career paths before they make it to the top.

THE TOP LOT. Invisible barriers exist all along the ladders. One that spans everything is the higher-degree barrier. Consider the pyramid structure of a company with the chief executive officer (CEO) at the top and the workers at the bottom. From informal surveys of fairly large engineering organizations, I judge that below the first-line supervisor, about 80 percent of the people have bachelor's degrees, about 15 percent have master's, and about 5 percent have doctoral degrees.

Between the first-line supervisor and the director, a mere 10 percent have bachelor's degrees, about 40 percent have master's degrees, and 50 percent are doctors. Between director and CEO, about 60 percent have doctoral degrees and 40 percent have master's degrees. In fact, a director or vice president may well have degrees in more than one area: a doctorate in engineering along with a master's in business. In my survey, I found no one at these rarefied levels with only a bachelor's degree.



[2] A product-oriented organization melds people with varying backgrounds on a single program.

So the message is clear: to become an upper-level manager, you need an advanced degree. Survey your own company. Find out how common advanced degrees are in your organization and which type of advanced degree virtually ensures getting ahead. If you are a mechanical engineer at an electronics company and all upper-level managers are electrical engineers, or if you are a programmer in a chemical company and all the advanced degrees are chemical, you can readily infer the promotion policies being followed.

In any case, do find out what types of degrees people have. There is nothing more flattering to a vice president than being asked about his or her background during a company party. They will immediately tell you everything they have accomplished. This is your opportunity. Ask what they would recommend for a younger employee. With any luck, you'll hear about shortcuts you need to know and hidden criteria for promoting.

PRODUCT ORIENTATION. Be aware of other organizational structures at your company in addition to the engineering ladder. These structures define the employees' roles and responsibilities, as well as the manner in which engineering tasks are accomplished. At most companies, engineers are organized into either product-oriented or functional-matrix structures.

In a product-oriented organization everyone works on the same product. Often the entire department is responsible for getting the product out the door. Everyone reports to a single top-level manager.

For example, in the organization for the ZX50 car [Fig. 2], the departmental manager has four subsystem departments reporting to him. The engine department is responsible for designing and testing engines, the body-design department for the exterior body, and so on.

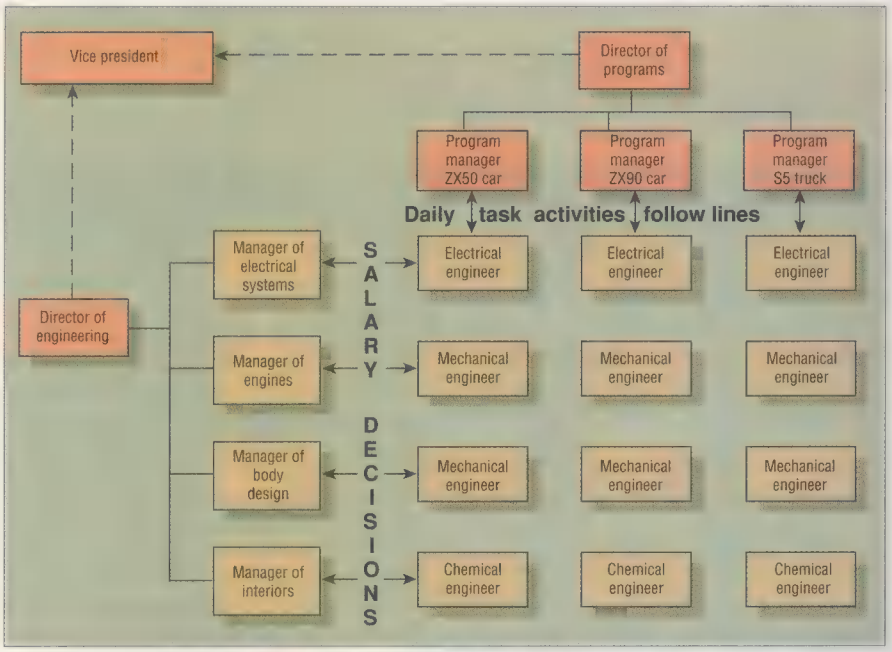
Those who report to the department manager are often the program manager and one or two staff engineers. The program manager determines what is to be worked on, and the engineering department finds the best technical approach. The work to be done is planned by the two managers together. A plus about this type of setup is that your work direction and salary review often come through your supervisor; one person, then, tells you what to do and hands out the raises.

Although in agreement as to the outcome, the program manager and engineering department manager may not see eye to eye. The first wants the fastest job done and the second wants the best engineering job—seldom identical goals.

A product-oriented organization offers several advantages. First, the organization gets to build the entire product, and seeing it all come together provides a real sense of accomplishment. If the product is a huge success, management knows whom to reward. Second, everyone reports through the same chain and decisions are more easily made.

OTHER PERSPECTIVES. Third, if the people you work with have very different backgrounds from you, dealing with them will broaden your own background. And since staffs now tend to be lean, you might be the only one in the group with your type of background—an excellent position, since there is no competition. Another advantage: if you have the same background as your supervisor or manager, they can understand your work more easily. Managers tend to promote people with backgrounds similar to their own. The rationale is: it worked for me and I am successful, so why not continue the trend? But if, say, you are a chemical engineer and your boss is an electrical one, she may not appreciate the great job you are doing.

Naturally, a product-oriented organiza-



[3] Large companies may group engineers with similar skills in a functional-matrix organization.

tion has disadvantages. If the product runs into trouble (because of poor planning or performance), you will be branded as coming from a failed program. Also, when product development ends, there is no place for you to go unless a new product is waiting in the wings. Finally, working on a product all too easily creates engineers who know everything about one little thing—not the best situation if you plan on running the organization some day.

MATRIX OF FUNCTIONS. In a functional-matrix organization, the company is grouped around functions. Members of a group generally have the same background but may not work on the same product.

The left-hand column of the matrix in Fig. 3 identifies departments by function. The top row identifies the projects within the company. In the example, three types of vehicles are produced: the ZX50 and ZX90 cars and the S5 truck. The top row identifies the program manager(s) responsible for getting work done.

Large companies find this organization efficient in running their business. People are grouped according to their skills; and they can be moved quickly on and off programs. Usually the supervisor determines salary increases and the program manager determines the work to be done.

This kind of organization can help your career in several ways. First, your colleagues have your sort of background, so someone who has faced something similar could help you if you get stuck on a problem. Second, you may work on more than one product at a time—a real plus if one of the products is pure tedium. Third, in a functional-matrix organization, you can quickly move from one product to another as the products come and go.

The functional-matrix organization, naturally, also has its down side. By and large, work direction comes from your program manager and technical direction from your supervisor—a tricky situation when the two disagree. Following your supervisor's direction may upset the program manager enough even to kick you off the product. Following your program manager's direction may upset your supervisor, who, of course, directly controls your salary.

You have two masters to please—and to get that raise, you must keep both happy. When it comes to a raise, the ultimate decision is up to your department supervisor, but you had better make sure the program manager agrees with him about your worth. It doesn't hurt to ask each of them how you're doing. It's better to find out before rather than after raises are given out, while you can still do something about it.

Another disadvantage of the functional-matrix organization is also one of its advantages—everyone in your group has a similar background and it's tough to stand out in a crowd. You must find ways to be different.

Few companies are organized strictly in either a product-oriented or a functional-matrix fashion. Rather, they are a mix of both. No one type of organization is better for your career than the other, but you need to recognize the differences and that what works in one may not work in another.

Find out how your company is organized and who determines your salary. You could be working hard to impress someone with no involvement in your raise. Make sure you report your progress at regular intervals to the person who does control it.

Recent engineering school graduates tend to come into a company believing that someone is looking out for them. They go off into a corner, do a great job, and expect their boss will reward them when they are finished. Remember, only you are looking out for you. So spend time each week with your supervisor. Let your boss know the problems you are solving. Ask for feedback on your performance. No one enjoys hearing criticism, but it's the only way you will be sure of turning things around.

HOMEWORK. Getting ahead also requires doing some homework—or more precisely, some on-the-job assignments:

- Map out the engineering ladder at your company. A good place to start is with your boss. Inquire about the levels of responsibility, next ask to see an organization chart and where you fit in.
- If possible, obtain a description of each level. Larger companies at one time or another have written this down. Smaller companies. are less formal, a state of affairs that may give the engineer greater freedom to perform tasks at all levels, but which may also lead to misunderstandings between employee and supervisor. So a job description may be more important at a small company than at a large one.
- Study the description for your current level and judge how you measure up. To get promoted, remember, you must be sure you are fulfilling each and every requirement. Next, study the level above yours and see how you and it compare.
- Find out how your company is organized—with a product-oriented or a functional-matrix organization, or a combination? Who reports to whom? Can you identify all the levels and who is at each level between you and the vice president? If you can you're in great shape! But if you don't know who they are, how can you expect them to know you and promote you?
- The final homework assignment is to determine the career path you want. How high up the ladder do you want to go? How much time will it take? What must you do to reach your goal?

TO PROBE FURTHER. Author Hoschette is scheduled to speak at a meeting next April of the Boston Section. Contact Barbara Roberts for the time and location at 617-271-2772; e-mail, broberts@mitre.org.

IEEE-U.S. Activities' Career Maintenance committee sponsors three career workshops geared toward helping engineers deal with change in their careers. Contact Scott Grayson, 202-785-0017; e-mail, s.grayson@ieee.org.

ABOUT THE AUTHOR. John A. Hoschette is a staff engineer with Loral Infrared and Imaging Systems in Lexington, Mass. An electro-optics expert, he has over the last 18 years worked in all phases of engineering projects, from field testing to the design and development of advanced systems, and the technical direction of several multimillion-dollar programs. Apart from Loral, Hoschette has worked for Northrop Corp. in Los Angeles and Honeywell Inc. in Minneapolis.

Program notes

A software sluice for electronic mail

With oceans of electronic mail now deluging their desktops every day, engineers are being overwhelmed by digital documents of one kind or another and struggling to find a labor-saving means of controlling the binary *tsunami*.

Any of three methods—algorithmic, linguistic, or heuristic—can be used to automate document classification and retrieval. The simplest is also the crudest, namely, the algorithmic, or rule-based, approach. Key words and topics in documents are identified by a family of rules and thereby equipped to determine where to store each document. The technique is unsatisfactory, however, because people write in ways that are too subtle and too complex stylistically to be analyzed by a finite set of rules.

The linguistic, or database, method is the most complex approach to archiving documents. Text in any given document is examined by means of a database of words plus their meanings, their relationships to other words, and their recommended storage locations. But there are problems—creating the database is costly and searching through one of usable size takes a long time.

The heuristic, or self-teaching, approach is a workable compromise between the algorithmic and linguistic approaches. The user sets up an initial file structure and walks the program through the classification and storage of a small number of documents. Each time the user stores a document, the program learns a little more about how he or she wants to handle the different kinds of documents in need of storage. After training, the program can handle most of the documents the user may wish to archive. It is more accurate than the algorithmic solution and faster than the linguistic approach.

The heuristic approach works because most users tend to store similar documents with a limited list of keywords linked by a few relationships. A program implementing the heuristic approach can be simplicity itself. It need learn only the rules relevant to the kinds of documents the user wishes to store and need search only for key words of interest to the user.

Island InTEXT, a Windows-based information management product by Island Software, adopts the heuristic style of analyzing and storing, as well as retrieving, documents. After training, the program will automatically sort and categorize Word for Windows and WordPerfect for Windows documents. Engineers who are trying to keep their heads above water when it comes to managing documents will find it a lifesaver. *Contact: Island Software, 715 Sutter St., Folsom, CA 95630; 916-985-4445; or* **circle 120**.

Too many cooks spoil processor broth

Most PC/AT-compatible manufacturers have released multiprocessor versions of their top-of-the-line personal computers, or have said that they will soon do so. Their aim is to take over workstation and client-server applications with these processor-rich models. Some of the content of these designs, though, is proprietary. So to cut down on this variable element, Intel Corp. is pushing MP Spec, its multiprocessor specification.

MP Spec describes how generic, DOS-compatible, PC/AT-capable, multiprocessor systems should be built when using Intel chips. It is intended, obviously, for original-equipment manufacturers and, less obviously, for developers of primary and built-in operating system (BIOS) software.

MP Spec is an extension of the PC/AT standard used on single-processor systems. It is based on Intel's instruction set and advanced programmable interrupt controller (APIC) architecture. A stand-alone chip that implements the APIC architecture is available for 80486-based systems. The Pentium chip already incorporates the APIC architecture.

Under MP Spec, the operating system obtains its information about hardware configurations from the BIOS. Information about the default hardware is kept by the BIOS in the data-area address space that is home to its multiprocessor floating-pointer structure. Data in the pointer structure indicates if the system conforms to MP Spec and points to the optional multiprocessor configuration table (if implemented), where information about non-default hardware is kept. The configuration table may be stored in nonreported system RAM or in the BIOS's read-only memory space. *Contact: Intel Corp., 2200 Mission College Blvd., Box 58119, Santa Clara, CA 95052-8119; 408-765-8080; or* **circle 121**.

The symmetrical desktop

Operating systems and application software developed for single-user, single-processor hardware cannot capitalize to the full on the potential of multiple processors. In general when this kind of software runs, all of the processors except one remain idle. To keep lots of them busy, both operating system and application software must be threaded, that is, divided into tasks that can be executed in parallel when extra processors are available.

Symmetrical multiprocessing (SMP) software is written to exploit a plurality of processors. It is usually benchmarked by measuring its run times on both a dual-processor system and a comparable single-processor one; the results are given as a ratio of the two run times. Scalable SMP software can exploit a good many processors without incurring a lot of overhead from managing their use. The scalable software is often benchmarked by increasing the number of processors until adding yet another makes system performance drop.

Among scalable SMP operating systems running on PC/AT-compatible hardware, IBM Corp.'s OS/2 2.11 for SMP is the current high-performance champion. Under OS/2 for SMP, IBM's DB2 database runs 1.8 times as fast on a dual-processor machine as on a single-processor unit. And performance continues to improve even when, in the case of a system that is compatible with Intel's Multi-Processor Specification [see previous item], a 16th processor is added.

Widespread adoption of standard multiprocessor specifications like Intel's will greatly simplify SMP and scalable SMP software development. At present, operating systems and application programs have to be tuned for each and every platform. The initial release of IBM OS/2 for SMP, for instance, contains software for seven distinct hardware platforms, as well as code for MP-compatible hardware. As more manufacturers become MP-compatible, the need to ship software for unique hardware platforms will diminish.

Meanwhile, programmers who want to convert single- into multi-processor applications that will run under SMP operating systems should take a look at MetaWare's High C/C++ compiler. High C/C++ ships with EasyThread, a unique tool that automates most of the labor of converting the application. *Contacts: IBM Corp., 1133 Westchester Ave., White Plains, NY 10604; or* **circle 122**; *MetaWare, 2161 Delaware Ave., Santa Cruz, CA 95060-5706; 408-429-6382; or* **circle 123**.

CONTRIBUTOR: John R. Hines is a silicon sensor engineer at Honeywell Inc.'s Micro Switch Division, Richardson, Texas.
CONSULTANTS: Bruce Mather, Phototelesis Corp.; Shari L. Fleeger, Systems/Software Inc.

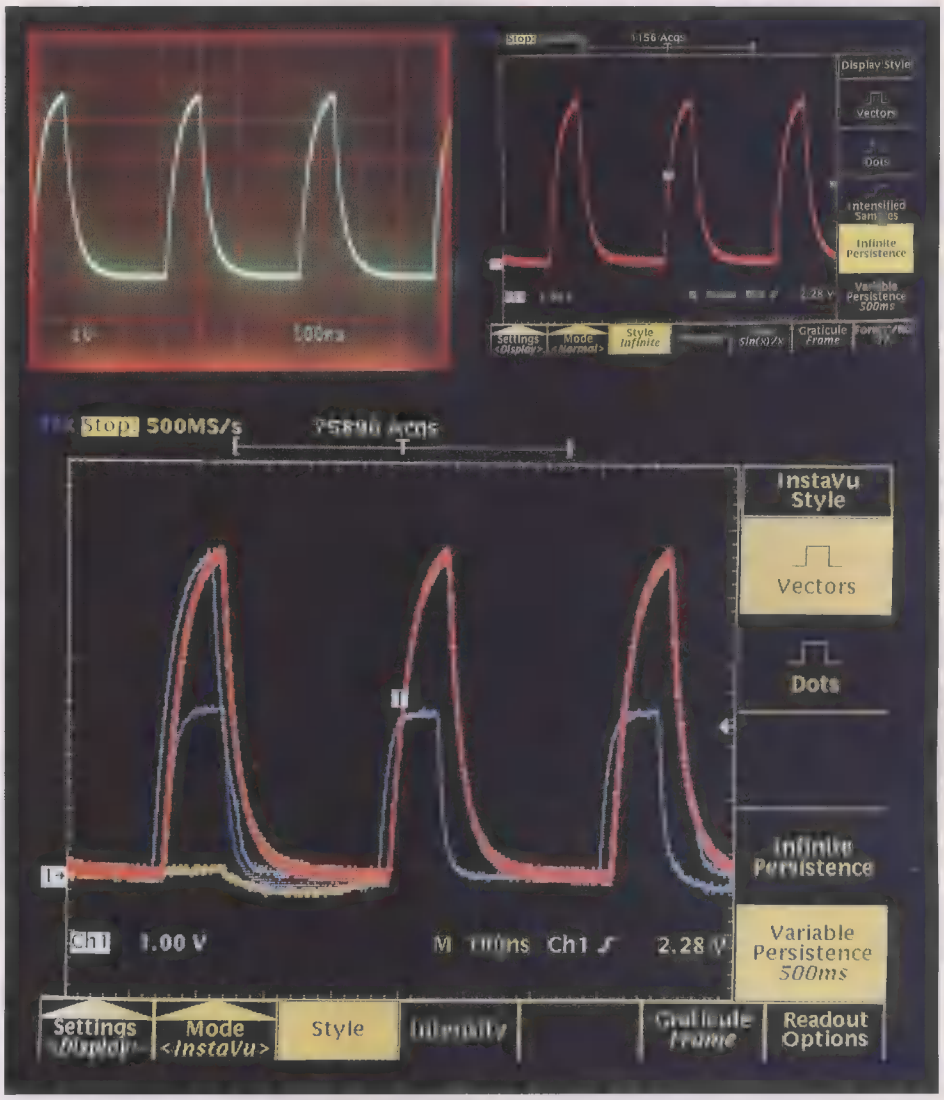
EEs' tools & toys

Digital scopes boast analog acquisition rates

In spite of the many obvious advantages of digital storage oscilloscopes (DSOs), many engineers still feel more comfortable with analog units. Familiarity is one reason. But the real issue, in most cases, is trust. Users simply have more faith in what they see on the face of an analog real-time scope than on a digital one. Now Tektronix Inc. has taken a giant step toward changing that situation by developing a family of DSOs that eliminates one of the main advantages of analog scopes—their far higher acquisition rates.

When operated in their InstaVu acquisition mode, scopes in the new TDS 700A family have only 1.7 μs of dead time between sweeps, compared with the 7–8 ms typical of other DSOs. Like the best of analog scopes, therefore, they are able to acquire signals at rates in excess of 400 000 waveforms per second. Conventional DSOs, by contrast, are hard pressed to acquire 100 waveforms in the same length of time.

Because they waste so little time between sweeps, the new DSOs have duty cycles that can exceed 20 percent, compared with less than 0.01 percent for conventional DSOs. So they are much more likely to capture those rare events that make intermittent problems so maddening to diagnose—the occasional missing or runt pulse, for example. Moreover, the new scopes color-code the infrequent events on the basis of their rarity. For those reasons alone, the new instruments will doubtless prove to be favorites in many troubleshooting applications.



Neither a conventional analog scope like the Tektronix 2465 [top left] nor a conventional digital scope like the Tektronix TDS 544A [top right] can be relied upon to catch such infrequent events as an odd runt pulse in a train of pulses. Capturing such rare events is child's play, however, for the TDS 784A in its InstaVu mode [bottom].

But there is much more to what Tektronix is calling its TruCapture family. The two scopes that currently make up the family feature multiple acquisition modes and a host of advanced triggering capabilities designed to simplify the capture of many types of signals. Among the triggering capabilities, for example, are a slew-rate mode, which enables designers to detect rise-time violations; pulse-width triggering; and a mode that recognizes unstable logic timing that violates setup-and-hold rules.

Both the new scopes are four-channel instruments, with each channel capable of a standard record length of 50 000 samples and an optional record length on one channel of 500 000 samples. Both also have a high-resolution mode that uses averaging to increase the vertical resolution from its basic value of 8 bits to more than 13 bits. And both offer dual window zoom with which engineers may look at normal and expanded views of a waveform simultaneously.

On-board digital signal processing capability allows both scopes to perform mathematical manipulations on acquired waveforms, turning raw data into meaningful information. Among the built-in functions are Fourier transforms, integration, and differentiation.

What distinguishes the two members of the TruCapture family are bandwidth and sampling rate. The TDS 784A has a bandwidth of 1 GHz, a maximum sampling rate of 4 gigasamples per second, and a price tag of US $34 495. The figures for the TDS 744A are 500 MHz, 2 gigasamples per second, and $17 750. *Contact: Tektronix Inc., Measurement Business Division, Box 1520, Pittsfield, MA 01202; toll-free, 800-426-2200; for a faxed data sheet, dial 800-763-3133 and ask for document number 10 000; or* **circle 101.**

Tools & toys

(Continued from p. 101)

DATA ACQUISITION

VMEbus and PC/AT bus products

The expanded line of precision VMEbus and PC/AT bus data acquisition products from Analogic Corp. is described in a new 104-page catalog. The covered products are for applications requiring 12-, 14-, and 16-bit resolution at data rates up to 1 megasample per second.

Featured in the new catalog is the FAST series of PC/AT boards, which provide on-board simultaneous sample-and-hold, measurement capabilities as high as 16 bits, sampling rates up to 1 MHz, and digital signal processor interconnection. In addition to the data-acquisition boards, software is also covered. The catalog is available free of charge. *Contact: Analogic Corp., 360 Audubon Rd., Wakefield, MA 01880; or* **circle 102.**

SOFTWARE

Macsyma adds matrices, animation

Past mathematical software fell easily into two main categories: numerical and symbolic. Now that distinction is disappearing as software companies either add the missing features directly to their products or create gateways (and appropriate legal arrangements) through which those features may be imported from other products.

Macsyma, the well-known symbolic math package, is no exception. Its 2.0 version includes a new Matpack module with over 300 commands and language features for specifying matrix operations. It also includes a translator for converting commands from Matlab, the favorite numerical math package, into Macsyma commands, so that users may run Matlab scripts under Macsyma.

Perhaps the most dramatic improvement in Macsyma is its graphics. With the animation included in Version 2.0, users can watch solutions to dynamic problems in motion. The program also provides fine control of plot labels, colors, lighting, and many other features. Its object-oriented graphics viewer enables users to set more than 200 attributes of a typical three-dimensional plot.

Along with a companion product, PDEase [Software Reviews, October, p. 74], Macsyma provides a comprehensive suite of symbolic and numerical tools for solving differential equations. Macsyma itself finds symbolic symmetries and solutions of systems of partial differential equations (PDEs) automatically. PDEase solves PDEs numerically by finite-element analysis.

Also new in Version 2.0 are executable notebooks, which combine text, mathematical expressions, and scientific graphics in a single document.

Macsyma for PCs running DOS will normally sell for $349 ($299, academic). But until the end of this year, it is being offered for $299 ($269, academic). Versions for most popular Unix workstations are also available. Bundled together, PC Macsyma and PDEase sell for $749 ($599, academic). *Contact: Macsyma Inc., 20 Academy St., Arlington, MA 02174; 617-646-4550; toll-free, 800-Macsyma (800-622-7962); fax, 617-646-3161; or* **circle 103.**

INSTRUMENTATION

A very friendly logic analyzer

In the two decades they have been around, logic analyzers have proven themselves invaluable in designing and debugging logic circuitry. At the same time, they have acquired a reputation for being difficult to use, causing many engineers to turn to them only when all other approaches to solving a problem have failed.



Looking more like an oscilloscope than the logic analyzer that it is, the HP 54620A was designed especially to appeal to users unfamiliar with logic analyzers. The 16-channel instrument has a sampling rate of 500 megasamples per second.

Now Hewlett-Packard Co. has found a way to make these powerful tools more attractive to designers who troubleshoot digital circuits with an oscilloscope because they do not want to take the time to master the complexities of a logic analyzer. The company has developed a simplified analyzer with the look and feel (and pricing) of a 100-MHz delayed-sweep oscilloscope. Called the HP 54620A, the new instrument is a 16-channel timing-only analyzer with a sampling rate of 500 megasamples per second.

The unit's front panel looks a lot like that of a traditional oscilloscope, with dedicated knobs for such commonly used controls as channel select, channel position, time per division, and delay [see photo]. Less frequently used controls and more complex features are implemented as menus keyed to six soft keys arrayed across the bottom of the screen. In the interest of simplicity, the menus are nested only one level deep, in most cases.

Perhaps the best illustration of the thinking behind the 54620A is its triggering system. For applications that require simple edge or pattern triggering, either mode may be selected at the touch of a dedicated button. For applications requiring more complex triggering, a third mode, called ADVANCED, allows two patterns to be defined and combined in various ways. That mode also allows the number of times a pattern repeats and its duration to be part of the trigger specification. Thus, complexities need be addressed only when the application unavoidably demands it.

The analyzer's 16 channels are grouped in two pods. Each pod's logic threshold may be set independent of the other for TTL, CMOS, ECL, or a user-specified voltage level. For each channel, the input impedance at the probe tip is 100 kΩ shunted by 8 pF.

The 54620A is priced at $2995. *Contact: Hewlett-Packard Co., Direct Marketing Organization, Box 58059, MS51L-SJ, Santa Clara, CA 95051-8059; toll-free, 800-452-4844, ext. 8598; or* **circle 104.**

RLC meter resolves 0.1 ppm

As companies both downsize and strive for ISO 9000 certification, calibration laboratories are coming under pressure to calibrate more instruments in less time and for less money. QuadTech's Model 7510 precision RLC meter is intended to help in that effort. A highly automated instrument, the meter is less susceptible to human error than many others. Moreover, its automatic accuracy calculation feature displays the uncertainty for each measurement.

The meter's frequency range extends from 10 Hz to 100 kHz. It has a basic measurement uncertainty of 0.01 percent and a seven-digit display, which resolves 0.1 ppm. Its maker, QuadTech, acquired the GenRad Instrument product line in 1991.

The 7510 is priced at $10 200. *Contact: Phillip H. Harris, QuadTech Inc., 45 Main St., Bolton, MA 01740-1107; 508-779-8300, ext. 6800; or* **circle 105.**

GENERAL INTEREST

'Video modem' sends color pictures

Suppose there is a problem with a machine on your manufacturing floor and you are about to call the manufacturer to discuss it. It would be helpful to show the folks at the other end of the line a picture of the malfunctioning device, but how can you do so?

Tools & toys

Easy, provided both of you have the latest piece of telecommunications gear from Sharp Electronics Corp.—the Viewcamteleport. What you then do is shoot a few seconds worth of the problem machine on a video camcorder, connect the camcorder to your Viewcamteleport, and send the manufacturer a selected frame or frames.

Essentially ▪ video modem, the Viewcamteleport (Model No. VR-MS1U) transmits full-color still video images over ordinary telephone lines. It requires only 8 seconds to send a low-resolution image, 11 seconds for medium resolution, and 20 seconds for its best-quality transmission.

Although the Viewcamteleport interfaces most conveniently with Sharp's VL-H410U Viewcam, it is equipped with audio and video I/O jacks for interfacing with other video sources as well.

In addition to transmitting recorded images, the combined Viewcam and Viewcamteleport can exploit the Viewcam's digital still/snap function to send a picture of whatever is in front of the camera, effectively turning the system into ▪ videophone. The two devices may also be left unattended to serve as an audio/video answering machine.

Note: the Viewcamteleport may be used to transmit pictures of smiling grandchildren as well as malfunctioning machines.

The Viewcamteleport has a suggested retail price of $899.95. The Viewcam's price is $2499.95. *Contact: Video Division, Sharp Electronics Corp., Sharp Plaza, Mahwah, NJ 07430; toll-free, 800-BE-SHARP; or* **circle 106.**

NEW & NOTEWORTH

• The latest version of the high-frequency structure simulator (HFSS) from the HP EEsof Division of Hewlett-Packard Co., Westlake Village, Calif., **computes the s-parameters of passive 3-D structures—even open-boundary structures like antennas.** In addition, HFSS version 3.0 has a fast frequency-sweep mode, which provides ▪ quick preview of ▪ structure's frequency response by limiting its analysis to a few frequencies within ▪ user-specified band. The simulator also boasts ▪ variety of user-interface improvements. Offered ▪s an upgrade at no charge to supported customers, HFSS 3.0 (Model No. HP 85180A) is priced at $41 800. For sales information, call 800-452-4844 or **circle 107.**

• Motorola's Customer Specified Integrated Circuits (CSIC) Microcontroller Division, Austin, Texas, has announced **10 new versions of the popular M68HC05 family of 8-bit microcontrollers** aimed at answering machine and corded and cordless telephone applications. Many of the parts include ▪ dual-tone multifrequency (DTMF)/melody generator, which supports DTMF dialing, melody-on-hold, and pacifier tone functions. The chips consume very little power and operate off very low supply voltages (as low as 2.5 V for some), making them well suited for use in battery-operated devices. **Circle 108.**

• Crystal Semiconductor, Austin, Texas, is offering ▪ **T1/E1 telephone line interface unit (LIU)** with such advanced features as software-selectable output signal levels and internal pulse-width control. The CS61577 consumes 34 percent less power than its predecessor, the CS61574, for which it is ▪ pin-for-pin replacement. The new chip will sell for $14 in lots of 1000. **Circle 109.**

• **A 10-W dc-dc converter** from Computer Products Inc., South Boston, Mass., fits in a package just 25 by 51 by 10 mm. It is offered in a wide range of input and output voltages, with efficiencies as high as 88 percent. Prices start at less than $50. **Circle 110.**

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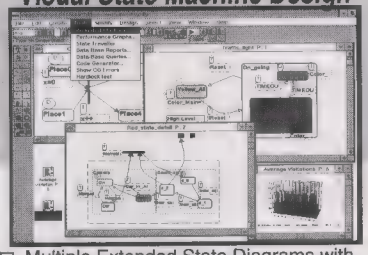
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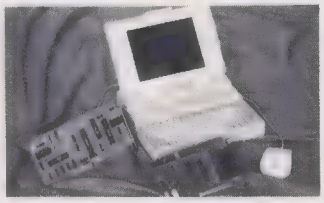
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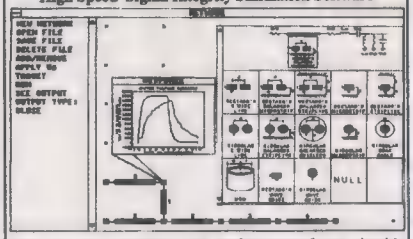


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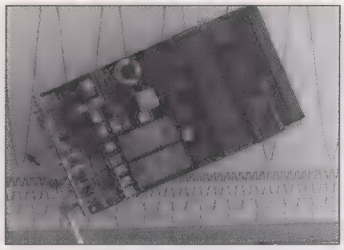
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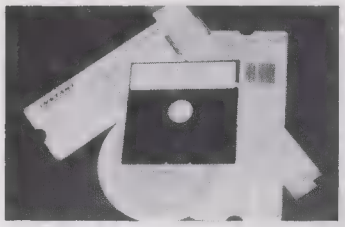
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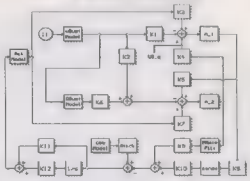


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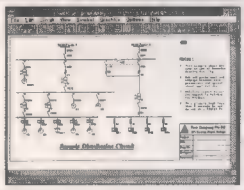
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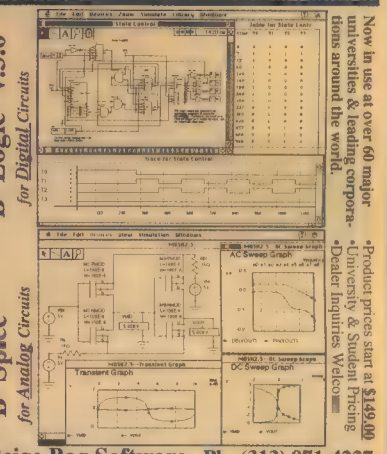
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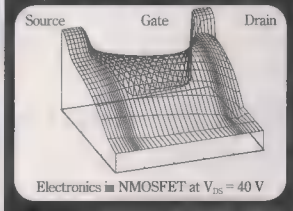
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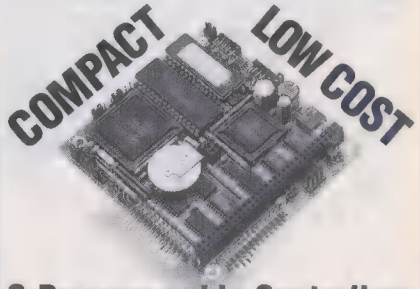
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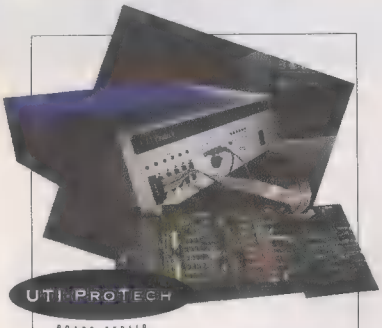
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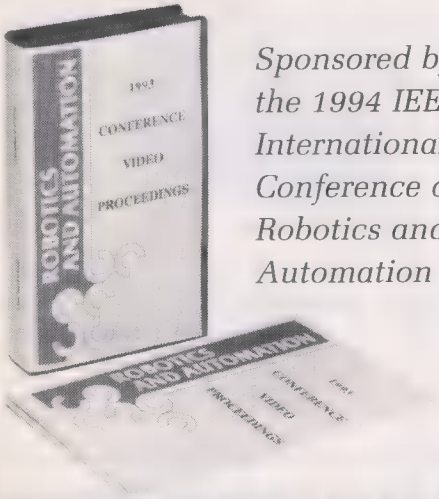
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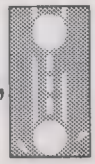
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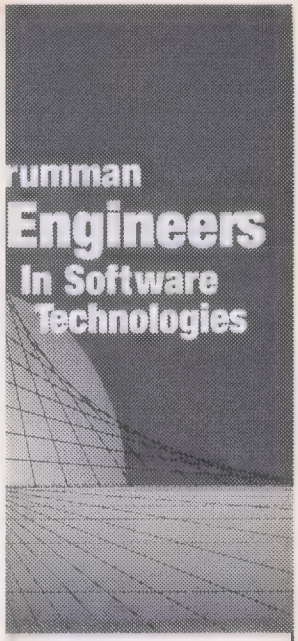
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Power Surge: Guide to the Coming Energy Revolution. *Flavin, Christopher,* and *Lenssen, Nicholas,* W.W. Norton & Co., New York, 1994, 384 pp., $23 (cloth), $10.95 (paperback).

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High-Resolution Radar, 2nd edition. *Wehner, Donald R.,* Artech House, Norwood, Mass., 1995, 593 pp., $89.

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MAY

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International Radar Conference (AES, NCAC); May 7–11; Radisson Mark Plaza Hotel, Alexandria, Va.; Tom Fagan, IEEE International Radar Conference, 1000 Wilson Blvd., 30th Floor, Arlington, VA 22209; 703-247-2988; fax, 703-276-9706.

Power Industry Computer Applications Conference (PE); May 7–12; Salt Palace Convention Center, Salt Lake City, Utah; Robert Chisholm, PacifiCorp., 1407 W. North Temple, Salt Lake City, UT 84140; 801-220-2109; fax, 801-220-2483.

Industrial and Commercial Power System Conference (IA); May 8–11; Menger Hotel, San Antonio, Texas; M. Osborn, 13622 Stoney Hill, San Antonio, TX 78231-1823; 210-671-2853.

International Conference on Acoustics, Speech and Signal Processing (SP); May 8–12; Westin Hotel, Detroit, Mich.; Al Hero, Department of EECS, 4229 Engineering 1, University of Michigan, Ann Arbor, MI 48109-2122; 313-763-0564; fax, 313-763-1503; e-mail, hero@dip.eecs.umigh.edu.

Seventh International Conference on Indium Phosphide and Related Materials (LEOS, EDS); May 9–13; Hokkaido University Conference Hall, Sapporo, Japan; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331; 908-562-3893; fax, 908-562-8434.

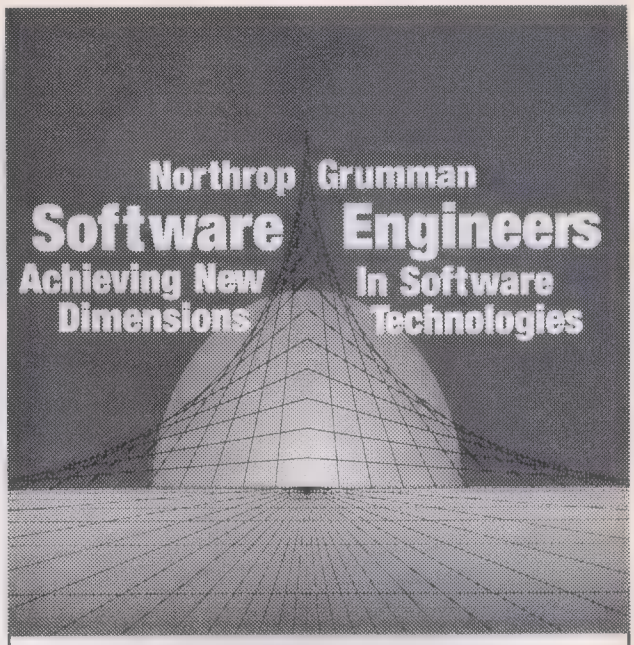
Microwave and Millimeter-Wave Monolithic Circuits Symposium (ED); May 15–16; Orange County Convention/Civic Center, Orlando, Fla.; Val Peterson, Hewlett-Packard Co., 1412 Fountaingrove Parkway, Building 1, Santa Rosa, CA 95403; 707-577-2304; fax, 707-577-4090.

International Microwave Symposium—MTT '95 (MTT); May 15–19; Orange County Convention Center, Orlando, Fla.; G. K. Huddleston, 506 Lisa Lane, Maitland, FL 32751; 407-339-0336; fax, 407-356-7201.

University/Government/Industry Microelectronics Symposium (ED); May 16–18; J.J. Pickle Research Center, University of Texas, Austin; Mahboob Khan, Advanced Micro Devices, MS 178, Building 965, Thompson Place, Box 3453, Sunnyvale, CA 94088; 408-749-4213; fax, 408-749-5585.

Pacific Rim Conference on Communications, Computers, Visualization, and Signal Processing (Victoria C); May 17–19; Victoria Conference Centre, Victoria, British Columbia; Mary O'Rourke, Conference Services, University of Victoria, Victoria, BC V8W 2Y2, Canada; 604-721-84656.

Third ACM Symposium on Solid Modeling and Applications (C); May 17–19; Red Lion Hotel, Salt Lake City, Utah; Mike Pratt, NIST, Building 220, Room A127, Gaithersburg, MD 20899-0001; 301-975-3951; fax, 301-258-9749; e-mail, pratt@cme.nist.gov.



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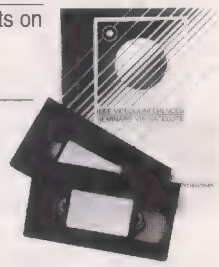
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Technically speaking

Spacy names

Dave Dooling, Contributing Editor

Spacecraft and launch vehicles by any other name will fly the same. But the how and why of naming them is, at best, erratic.

One of the most confusing elements is whether they should be known by Roman or Arabic numericals. As revealed by a painstaking search of historical documents at the National Aeronautics and Space Administration, both may be applied to the same vehicle.

Thus, the U.S. crew setting out for the moon back in 1969 lifted off atop the Saturn V, not the Saturn 5, rocket—although that rocket began life a number of years before as the Army's C-5. (Perhaps the V was chosen because it looks more distinguished.) The designation of Saturn was picked because the planet Saturn is next out from Jupiter, the name of the previous missile developed by the U.S. Army.

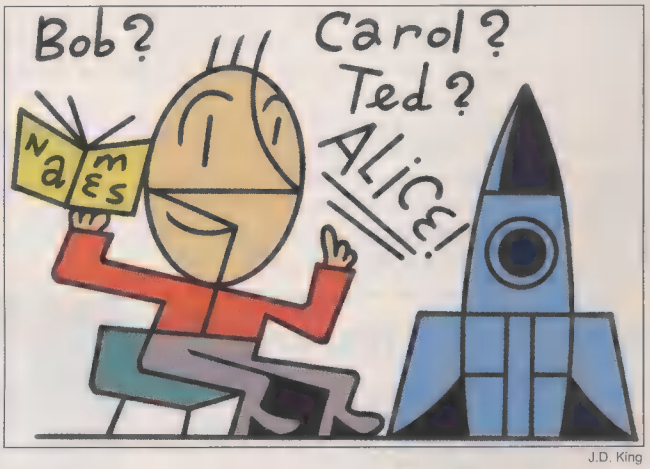
Numbers are perplexing in other ways. Following the 1957 launch of the first space satellite, the Soviet Union's Sputnik 1, the United States assessed its launch vehicle needs and decided to categorize the vehicles on the basis of payload weight, lumping everything into three broad categories, A, B, and C. The clustered-engine vehicle the Army was developing at the time became the C-1; the largest in the series became the C-5. As the C-1 took shape and was transferred to NASA, it was renamed Saturn I. Eventually, only the largest was selected for development as the Saturn V.

Then, to confuse matters, the individual stages of the Saturn each got names of their own. Saturn I's first stage became the S-I; its improved version was the S-IB. The Saturn V first stage became the S-IC, although, apart from similar propellants, it had nothing in common with the S-IB The second stage became the S-II and the third stage was tagged not the S-III but the S-IVB, a follow-on to the S-IV second stage used on the Saturn I.

Earlier names are hardly better. The Army's first successful ballistic missile was the Redstone, named for that service's Redstone Arsenal in Huntsville, Ala. (Army surveyors had used a red stone as a benchmark in 1940.) Redstone was to be followed by the more powerful Jupiter missile. To save money, the Army planned to test models of the Jupiter warhead that were actually Redstones capped by clusters of small solid rockets.

But the Redstone had no priority at the Cape Canaveral Air Force Station, where the launches were scheduled to take place. So the Army resorted to subterfuge, designating the modified Redstones the Jupiter A and B series. In 1958, Jupiter C, with a single solid rocket added as a fourth stage, launched the first U.S. satellite.

The names for satellites can have quirky underpinnings. Back in 1958, the one for that first U.S. satellite was chosen by elimination. Space scientists Wernher von Braun and James van Allen began with a list of people for whom they thought the satellite might be named, and eliminated the candidates one by one. Finally, all they had was the name of the list: Explorers. That name is still used today for a broad range of medium-cost science satellites.



J.D. King

Satellite numbering, though, only seems odd. Before launch, a satellite goes by a letter, like the F in NOAA-F, but once in orbit and operating, it is assigned a number. In fact, the numbers may be forced into sequence. On the Voyager probes of the outer solar system, for example, the numbers were swapped so that the first to arrive at Jupiter would be called Voyager 1 and the second, Voyager 2, even though they were launched in reverse order. The second spacecraft was sent off on a faster trajectory, and a unique planetary alignment was exploited that had Jupiter accelerate the craft past another three planets. (Voyager's name originally belonged to a complex Mars lander program that was scaled back and became Viking.)

Perhaps the most durable of the satellite rubrics was coined by the former USSR, which launched more than 2200 of its Kosmos series after the first satellite went up in March 1962. Kosmos has embraced spy satellites and research craft, as well as failed payloads and tests of new spacecraft.

As for U.S. satellites, the military ones are easy to spot. They have bland names or else stick to alphanumerics, as is the case with the Defense Support Program Satellites, which in actual fact watch for ballistic missile launches. It's not easy to boast that, "Yeah, I'm the guy that launched the old AFP-647." Classified projects such as this one rarely, if ever, have morale-boosting nomenclature.

Earlier this year, nevertheless, the U.S. Ballistic Missile Defense Organization indulged in a little whimsy when it gave its moon-orbiting surveyor craft the name of Clementine. But then, the craft's mission was hardly military: it was to prospect for minerals on the moon (which it did) and was then to go on to an asteroid (which it failed to do). Eventually, the craft would be "lost and gone forever," which are the words of an old American folk song, "My Darling Clementine." Alice, a proposed follow-on, would honor the often uttered, but never fulfilled, clenched-fist threat made by the old-time U.S. television character Ralph Cramden to his long-suffering wife: "One of these days, Alice, to the Moon!"

Back in 1961, astronaut Gus Grissom was thinking along the same lines. After his Liberty Bell 7 Mercury capsule sank from under him during its recovery in the Pacific Ocean, he wanted to name his next craft "The Unsinkable Molly Brown," after a Broadway show of the time. But NASA had had enough of names chosen by the astronauts (along with Liberty Bell 7 there was Freedom 7 and Friendship 7, for example) and made Grissom stick with Gemini 3. Personalized names returned, though, when call signs were used.

At about the same time and for similar reasons, NASA's Lunar Excursion Module lost its middle name because some considered it frivolous. When call signs had to be used for two Apollo spacecraft operating at the same time, the sporty Gumdrop and Spider gave way to the patriotic Columbia and Eagle in just three missions.

The space shuttle was yet another ball game. What to call the individual shuttles was a hot topic in the mid-1970s. Under heavy pressure from *Star Trek* fans, U.S. President Gerald Ford dubbed the first winged earth-orbiter Enterprise in 1976 (reportedly, NASA had selected Constitution). But the space agency had an

Technically speaking

out: Enterprise was also the name of one of its small research ships, so the agency need not appear to be knuckling under to TV viewers.

And in 1977, NASA administrator Robert Frosch tapped his original profession, oceanography, to name Columbia, Challenger, Discovery, and Atlantis after famous oceanographic vessels. The name Challenger was retired after that space shuttle blew up shortly after launch in 1986, killing all seven aboard. Its replacement was named Endeavour (with the British "-our"), following a contest among U.S. school children. The name Discovery is also applied now to a new generation of low-cost planetary probes.

During 1984–86, shuttle missions were denoted in a code developed by Lieutenant General James Abrahamson, then on loan from the U.S. Air Force and a NASA associate administrator. The first digit indicated the fiscal year, the second indicated the launch site (Kennedy Space Center in Florida was 1, Vandenberg Air Force Base in California was 2), and last came a letter for the series. For example, 51-L was to have been the 12th launch from Kennedy in FY85. It retained that name even though its launch slipped into 1986. NASA resumed using simpler sequential numbers for the space shuttles with STS-26, -27, and so on, after the Challenger tragedy. (By the way, the Columbia mission of last July was STS-65.)

Whereas the military once accepted names that their manufacturers assigned to aircraft, NASA has always assigned its own names. Thus, the agency was less than happy with the principal investigator for the second High Energy Astronomy Observatory (HEAO-2), Riccardo Giaconni, then with the Smithsonian Astrophysical Observatory, Cambridge, Mass., when he told a press conference just before launch in 1978 that the scientists had christened it the Einstein Observatory. It is rarely called that in official NASA reports.

The names of shuttle payloads often are acronyms for complex descriptions of their missions. Someone tried to do this for Spartan, the name of small astronomy satellites deployed and retrieved by the shuttles. The program manager rebuffed the attempt, however, stating that he wanted Spartan to reflect its budget and design philosophy.

Other acronyms range from Solar Optical Telescope—SOT, "the most unfortunate acronym in NASA," its manager moaned—to the Wisconsin Ultraviolet Photometric Polarimetry Experiment—Wuppe (pronounced "whoopee"). The unflown SOT was also for a short time the Solar Optical Laboratory, until NASA realized that SOL also described its condition—Sure Outta Luck. This summer's SpaceLab mission carried a French electrophoresis apparatus whose acronym, in French, was Ramses. Not until a few weeks before launch did the French scientists realize that the name refers to a U.S. brand of condom, but it was too late to change.

That points up the need for caution when naming a spacecraft. Perhaps the most notorious example to slip by was the Spacecraft Charging at High Altitudes. After its launch in 1978, someone realized that its acronym Scatha was Greek for excrement.

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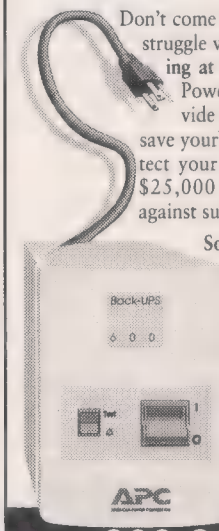
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Academic Positions Open

Washington State University at Tri-Cities, School of Electrical Engineering and Computer Science: One faculty position at the Assistant or Associate Professor level is available starting at the beginning of the 1995-96 academic year, sited at WSU Tri-Cities in Richland, WA. A PhD in electrical engineering or a closely related field is required. The successful candidate will contribute to instruction at the undergraduate and graduate levels in electrical engineering and maintain an active research program. Areas of research interest include power, computer engineering, the nondestructive testing of materials, and electromagnetic field theory. Industrial experience is desirable. Applicants should provide a resume and a list of three references including addresses, phone numbers and the rank they are applying for. First deadline for applications is October 30, 1994 but applications will be entertained until position is filled. Address correspondence: Chair, Search Committee EECS, WSU Tri-Cities, 100 Sprout Road, Richland, WA 99352. WSU is an EO/AA educator and employer. Protected group members are encouraged to apply.

Lehigh University: The Department of Electrical Engineering and Computer Science seeks applicants for a tenure-track faculty position. Candidates must have a PhD in computer engineering, computer science, or electrical engineering. We require a strong commitment to teaching and evidence of innovative research through appropriate journal publications. Preferred areas include: computer architecture, manufacturing applications, networking, optoelectronics, and software systems. We offer programs in computer engineering, computer science and electrical engineering leading to a PhD degree. Lehigh University is an affirmative action/equal opportunity employer. Women and minorities are encouraged to apply. Please send vita and names of at least three references to Dr. Alastair McAulay, Faculty Search Committee, Department of Electrical Engineering and Computer Science, Lehigh University, 19 Memorial Drive West, Bethlehem, PA 18015.

Chair, Department of Electrical Engineering: The University of Texas at Arlington invites applications for the position of Chairperson, Department of Electrical Engineering. Duties will assume in summer or fall of 1995. Candidates should hold an earned doctorate in Electrical Engineering, have a commitment to educational programs at both the undergraduate and graduate levels, and be recognized as a leader in research and education. The Chairperson will provide leadership in the ongoing growth of the department, including fostering strong relationships with government agencies and the extensive Dallas/Ft. Worth industry. UTA has 23,000 students and the largest College of Engineering in north Texas. The EE Department is situated in a new building and has 30 full time faculty, 500 undergraduate students, 300 masters students, and 100 Ph.D. students. Facilities include 67,000 sq. ft. of research and educational laboratories in: the NSF Industry/University Center for Electronic Materials, Devices and Systems, the Wave Scattering and Remote Sensing Research Center, the Energy Systems Research Center, the Human Systems and Performance Institute, the Medical Imaging Laboratory, the Applied Physical Electronics Center, the Electro-Optics Laboratory, and Telecommunications and Signal/Image Processing Laboratories. UTA's Automation and Robotics Research Institute provides 48,000 sq. ft. of additional facilities for interdisciplinary R&D in manufacturing, robotics, and controls. The EE Department has significant external funding from NSF, DoD, ARPA, and other government agencies, as well as from local Dallas/Fort Worth industry. A complete resume and the names of five references should be sent to: Professor Don Wilson, EE Chairman Search Committee, Box 19016, The University of Texas at Arlington, Arlington, Texas 76019. Tel. 817-273-2603, fax. 817-794-5010, email wilson@mecad.uta.edu. UTA is an affirmative action equal opportunity employer.

The University of Cincinnati, Electrical and Computer Engineering Department. Applications are solicited for a tenure track Assistant Professor faculty position in the Department of Electrical and Computer Engineering starting January, 1995. The prospective faculty member should have an earned Ph.D. in Electrical Engineering. S/He is expected to develop a research program with external funding and documented scholarship and to collaborate with established research programs in the area of millimeter-wave and photonic devices, circuits and systems. Applicants with expertise in epitaxial growth (particularly MOCVD) of III-V semiconductors will be preferred. An Aixtron Model 200 reactor and associated state-of-the-art x-ray and photoluminescence characterization facilities are available. The Department offers MS/Ph.D. programs in electrical engineering, computer engineering, and computing sciences as well as an ABET fully-accredited under-graduate program in Electrical and Computer Engineering. The Department has 30 full-time faculty, 200 full-time graduate students, 400 undergraduate students. Curriculum vitae and the names of four references should be sent to: Prof. Peter B. Kosel, Interim Head, Electrical and Computer Engineering Department, P.O. Box 210030, University of Cincinnati, Cincinnati, Ohio 45221-0030. The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

Assistant/Associate Professor: The Applied Science Department of the University of Arkansas at Little Rock (UALR) invites applications for a full-time tenure track faculty position at the Assistant/Associate Professor level. A Doctorate in Electrical Engineering or related field is required. The position will be filled as early as January 1, 1995. The Department is an interdisciplinary graduate level only program offering the M.S. and Ph.D. degrees. The Department emphasizes applied research in optics, electronics and signal processing and their applications to the measurement and control field. The successful candidate will have experience in one or more of the following areas: signal processing, microprocessor applications, instrumentation, or analog and digital communications. He/She will be expected to teach and develop graduate courses, supervise graduate students, and establish independent sponsored research programs. Industrial experience is desirable. Apply with a letter stating professional objectives, resume, and the names of three references to Dr. Emil C. Muly, Chair, Department of Applied Sciences, The University of Arkansas at Little Rock, ETAS 575, 2801 South University, Little Rock, AR 72204-1099. The University of Arkansas at Little Rock is an equal opportunity affirmative action employer and actively seeks the candidacy of minorities, women, Vietnam era veterans and persons with disabilities. Under Arkansas law, all applications are subject to disclosure.

Rice University, Department of Electrical and Computer Engineering, is seeking imaginative and dynamic candidates with an exceptional record of research accomplishments in the area of electronic materials for the Stanley C. Moore Chair in Engineering. The successful candidate is expected to perform an innovative research program in an area of electronic materials and/or devices which transcends traditional boundaries. Of particular interest is research being performed on the nanometer scale, complementing the newly-announced Nanotech-nology Initiative at Rice, the Rice Quantum Institute, and the Physical Electronics group of the ECE Department. The candidate must also have a strong commitment to teaching at both the undergraduate and graduate level. Candidates should send a resume, including names of references and research description, to the Chair, ECE Department, Rice University, Houston, TX 77251-1892. Applications should be received by January 1, 1995. Rice University is committed to attracting qualified persons of diverse backgrounds to its faculty, and is an Equal Opportunity/Affirmative Action Employer.

Cornell University - Faculty Positions: The Cornell University School of Electrical Engineering has faculty openings at all levels in information technology. We are especially interested in applicants for senior positions and in applicants interested in the design of digital systems. Candidates should have strong commitments to and outstanding achievements in research and teaching. Applicants' research areas should articulate with the National Information Enterprise, broadly construed to include such disciplines as: cable, fiber and wireless communication and computer networks; processing, compression, recognition, interpretation, security, distribution, retrieval and display of data, speech, image, video and multispectral signals; machine vision, machine learning, and architectures for parallel and distributed algorithms; human-machine interfaces with emphasis on handicapped access; broadband switching and high performance computing in support of such applications as interactive TV and HDTV, teleconferencing and telemedicine. Interested persons should submit a letter of application, professional resume, and the names of at least four references to: Director, School of Electrical Engineering, Phillips Hall, Cornell University, Ithaca, NY 14853-5401. Cornell University is an Affirmative Action/Equal Opportunity Employer.

University of Illinois at Urbana-Champaign: The Department of Electrical and Computer Engineering invites applications or nominations for a tenure track or tenured faculty position with expertise in one or more of the following fields: laser and optical physics, laser spectroscopy, low temperature plasmas, advanced concepts and diagnostics in plasma processing and chemistry, in situ processing of nanostructures, design fabrication, and packaging of electronic and optoelectronic integrated systems. Preference will be given to experimentalists with industrial experience. Applicants for tenure track positions at the assistant professor level must have an earned Ph.D., and an ability to teach effectively at both the graduate and undergraduate levels. Selected candidates must be able to initiate and carry out independent research, and perform academic duties associated with our B.S., M.S., and Ph.D. programs. A senior level appointment with tenure is also

possible for individuals of national or international stature. Applications should be received by January 15, 1995, in order to receive full consideration. Salary is open and based on qualifications. Starting date is negotiable, but it is preferred to be no later than August 21, 1995. Send resume, including names and addresses of at least three references and a list of publications, to: Search Committee, Department of Electrical and Computer Engineering, University of Illinois, 155 William L. Everitt Laboratory, 1406 West Green Street, Urbana, IL 61801. Telephone: (217)244-7096. The University of Illinois is an equal opportunity/affirmative action employer.

Carnegie Mellon: Graduate Study in Engineering and Public Policy (EPP) leads to a research-based Ph.D. specializing in policy issues in areas such as: telecommunication, computer and other information technologies; energy and environmental systems (including climate change); technical issues in international security; manufacturing and industrial policy; and risk analysis. Applicants must hold BA or BS in engineering, physical sciences, or math. Education or experience beyond the BS very desirable. Contact Denise Murrin-Macey, Engineering and Public Policy (06), Carnegie Mellon, Pittsburgh, PA 15213.

The Department of Electrical Engineering at Duke University is seeking three outstanding faculty members in key areas which are important to its programs, including Computer Engineering, Controls, Electromagnetic Propagation and Wireless Systems, Communications and Signal Processing. Duke is one of the nation's top research institutions and the undergraduate and graduate student body in the School of Engineering is very highly ranked. Candidates who have an established record of excellence in sponsored research and teaching should send their curriculum vitae with a letter of candidacy and the names of five references to: Faculty Search, Department of Electrical Engineering, Box 90291, Duke University, Durham, NC 27708-0291. Duke University is an equal opportunity/affirmative action employer.

Post-Doctoral Research Fellow in Photonics: The Optoelectronic Components and Materials group at the Center for Photonics and Optoelectronic Materials (POEM) at Princeton University is seeking applications from qualified candidates for appointment as a Post-Doctoral Research Fellow with expertise in organic electroluminescent and nonlinear optical devices. Prospective candidates should have a PhD in electrical engineering, materials science, physics or associated fields, and should have hands-on, in-depth experience with the design, vacuum deposition, device fabrication, analysis and characterization of active optical components such as light emitters, waveguides, modulators, etc. Successful candidates should be able to work alone on independent research projects, as well as lead and organize larger group activities consisting of graduate students at all levels of expertise. Appointments are for one year with possibility for extension. Salary level to depend on degree of experience. Candidates should send their resume and three letters of reference to Prof. Stephen R. Forrest, ATC/POEM, EQUAD J-301, Department of Electrical Engineering, Princeton University, Princeton, NJ 08544. Princeton University is an Equal Opportunity Employer.

North Carolina State University, Department of Electrical and Computer Engineering: Applications are invited for faculty positions in electrical and computer engineering at all ranks. Qualifications include an outstanding academic record, a doctorate or equivalent in electrical or computer engineering, or a closely related discipline, and a strong commitment to excellence in teaching and research. We are especially interested in candidates specializing in: (1) communications and signal processing with applications to multi-media and personal communications systems, (2) computer engineering including hardware/software design of personal digital systems and distributed digital systems and (3) real-time control. Successful candidates will have the opportunity to work with highly qualified faculty and outstanding students in a range of well-equipped laboratories. Please send your resume to Professor J.R. Hauser, Department of Electrical and Computer Engineering, Box 7911, North Carolina State University, Raleigh, NC 27695-7911. North Carolina State University is an equal opportunity, affirmative-action employer.

West Virginia University. The Department of Electrical and Computer Engineering at West Virginia University anticipates openings in all areas of Electrical and Computer Engineering. Salary and rank will be commensurate with qualifications. Positions will be tenure track. Applicants must have the Ph.D., must have potential for high quality teaching, and will be expected to initiate research and participate in departmental research programs. A curriculum vitae and cover letter identifying an area of specialization should be sent to: Faculty Search Committee, Department of Electrical and Computer Engineering, West Virginia University, PO Box 6104, Morgantown, WV 26506-6104. Applications will be received and considered immediately and searches will continue until all available positions are filled. West Virginia University is an affirmative action/equal opportunity employer.

Faculty Position in Electrical Engineering: The Electrical Engineering Department at the University of North Dakota invites applications for two tenure-track positions beginning August 16, 1995, at the assistant or associate professor rank. An earned doctorate is required. The department offers an ABET accredited BSEE, and masters degrees in electrical engineering and participates in the interdisciplinary Ph.D. program in energy engineering. Candidates with specialties in digital/analog electronics, expert systems, communications, signal processing, or power and energy systems are preferred. Teaching duties will include foundation and upper-level courses, design projects, laboratory development, and thesis supervision. Successful candidates are also expected to conduct scholarly research and to attain professional registration status. Please send letter of interest, resume, and the names of three references to the Chair, Search Committee, Electrical Engineering Department, UND, P.O. Box 7165, Grand Forks, ND 58202. Applications will be received until positions are filled. Review of applications will begin on October 1. UND is an affirmative action/equal opportunity employer.

Faculty Positions: The University of Alabama at Birmingham invites applications for faculty openings in the areas of Controls and Telecommunications. The successful candidates must hold both an ABET-accredited undergraduate degree and an earned doctorate in electrical engineering. The successful candidate for the controls' position should have significant teaching and research experience and qualify for appointment as an Associate Professor or Professor. The successful candidate for the telecommunications' position should exhibit potential as a teacher and researcher and qualify for appointment as an Assistant Professor. Letters of application will be received until the positions are filled; must indicate the position being pursued; must include an up-to-date curriculum vitae (that includes academic and industrial experience, professional publications, extramurally funded grant and contract support, professional recognitions [e.g. awards and patents], and status relative to registration as ■ Professional Engineer), a list of three (3) references, ■ brief statement of the applicant's educational philosophy, and a detailed statement of the applicant's research interests; and must be mailed to Dr. David A. Conner, P.E.; Professor and Chairman; Department of Electrical and Computer Engineering; BEC 261E; University of Alabama at Birmingham, Birmingham, AL 35294-4461. UAB is an EO/AA Employer.

Delft University of Technology (Netherlands). The Department of Electrical Engineering invites nominations and applications for a full-time tenured faculty position at the rank of full Professor, effective February 1995. The appointee will be involved in teaching and research in the area of application-specific embedded computer systems with an emphasis on the design of parallel and distributed systems. The successful candidate should have a distinguished record in computer architecture and design, which demonstrates the ability to provide leadership for academic programs and to conduct innovative and collaborative research. The individual selected for this position must posses a Ph.D degree or equivalent experience and proven didactic skills. Applicants should submit a resume, a publication bibliography and the names of at least three references to: Prof. Dr. ir. E. Backer, Dean of E.E., P.O. Box 5031, 2600 GA Delft, the Netherlands, quoting vacancy No. ET9413.

Chair, Department of Electrical Engineering: Applications are invited for the position of Chair, Department of Electrical Engineering, Wright State University, Dayton, Ohio. The department has 16 full time faculty, approximately 375 undergraduate majors and 85 graduate students. Undergraduate degrees in Electrical Engineering and Engineering Physics are accredited by ABET. The EE Department is one of four departments in the College of Engineering and Computer Science. The college has a total enrollment of about 1,500 undergraduate majors and 325 graduate students. The college programs are consolidated in a new engineering building with superb classroom, laboratory, office and computer facilities. An active research program is being conducted with significant external funding in several areas including image and signal processing, VLSI circuits, power electronics, applied communications, sensor fusion, control theory, robotics, microwave circuits, and electromagnetics. The position requires a Ph.D. in Electrical Engineering or closely related field with qualifications for advanced rank appointment in the department. A candidate must have a strong interest and dedication to educational programs at both the graduate and undergraduate level, a distinguished record in electrical engineering, and a demonstrated leadership ability in education and research. Applications should include a vitae, a statement of capabilities and qualifications, and names, addresses and telephone numbers of at least three professional references. The salary is competitive. Wright State University is an equal opportunity/affirmative action employer. Address applications to: Search Committee Chair, Department of Electrical Engineering, Wright State University, Dayton, OH 45435. Review of applications will begin December 1, 1994.

The Citadel: The Department of Electrical Engineering invites applications for a tenure track position at the Assistant Professor level. We are seeking an individual with a strong commitment to undergraduate engineering education, and the ability and desire to teach in an undergraduate Electrical Engineering program that includes both day and evening classes. A Ph.D. in Electrical Engineering is required: teaching and industrial experience are desirable. Applicants should be US citizens or have a permanent visa. The individual selected will have education and experience in the following areas: digital systems, microprocessor applications, instrumentation, and digital communications. Duties will include teaching a broad range of undergraduate lecture and laboratory courses; no graduate courses are offered. Institutional support for research is available and consulting opportunities are available in the metropolitan area. The position is to be filled by January 15, 1995, but applications will be accepted until the position is filled. The Citadel is a great place to work and beautiful, historic Charleston is a wonderful place to live. Applicants should send a letter stating professional objectives, a complete resume, including names and addresses of three references to Dr. Harold W. Askins, Jr., Professor and Head, Department of Electrical Engineering, The Citadel, 171 Moultrie Street, Charleston, SC 29409. The Citadel is an equal opportunity, affirmative action employer. Women and minorities are encouraged to apply.

The Department of Electrical Engineering at Tulane University invites applications for a full-time, tenured or tenure-track faculty position depending on academic standing, for Fall, 1995. The successful candidate will be expected to participate in teaching both undergraduate and

graduate students as well as in the development of ■ research program. The department currently has programs in communications, computer applications, control, power, and signal processing. The applicant must have ■ doctorate or have satisfied all requirements for the doctorate in Electrical Engineering or ■ closely related field by inception of employment. The applicant must also have a strong commitment to excellence in teaching and research. Complete vitae with a minimum of three references should be sent to Dr. Enrique Barbieri, Chairman Search Committee, Department of Electrical Engineering, Tulane University, New Orleans, LA 70118-5674. Screening will begin January 1, 1995 and will continue until the position is filled. Tulane University is an equal opportunity/affirmative action employer.

Northeastern University, Computer Engineering: The Department of Electrical and Computer Engineering invites applications for a tenure-track position in Computer Engineering at Northeastern University in Boston, MA. Potential candidates should have obtained ■ Ph.D. in Electrical or Computer Engineering, and should possess ■ strong publication record. Areas of research interest include: Computer-Aided Design, VLSI, Fault-Tolerance and Testing, Computer Architecture, and Parallel and Distributed Systems. Northeastern University is located in downtown Boston, ■ top cultural center of the northeast. The Electrical and Computer Engineering Department currently staffs 45 full-time faculty members. Being located in a major metropolitan area, there is substantial opportunity for obtaining industrial-based funding. The Department ranks in the top 20 nationally among universities in the amount of funded research. The Computer Engineering faculty is committed to excellence in research as well as innovation in graduate and undergraduate education. Please send letter of application, vita, and a list of four references (including email addresses) to: Prof. David R. Kaeli, Computer Engineering Search Committee, Dept. of Electrical and Computer Engineering, Northeastern University, 409 Dana Research Center, Boston, MA 02115. Northeastern University is an Equal Opportunity/Affirmative Action employer. The University strongly encourages applications from female and minority candidates.

Postdoctoral Position, Department of Radiology, University of Cincinnati: A postdoctoral position is available immediately to develop non-invasive quantitative, state-of-the-art diagnostic imaging techniques for the measurement of blood flow, particularly Doppler ultrasound and magnetic resonance angiography, as well as for the ultrasonic measurement of brain tissue structure and composition. A Ph.D. in engineering, physics, or medical physics and strong experience in experimental ultrasound and/or MR research are required. Applicants should send ■ curriculum vitae and references to: Christy K. Holland, Ph.D., Department of Radiology, University of Cincinnati, M.L. 742, 234 Goodman Street, Cincinnati, Ohio 45267-0742, Tel: (513) 558-0400, Fax: (513) 558-4867.

University of Toronto, Department of Electrical and Computer Engineering: The Department of Electrical and Computer Engineering invites applications for a tenure-stream Assistant Professor position in the area of microelectronics. The applicant is expected to have a strong research interest in integrated circuits design for signal processing and/or communications applications using leading-edge technologies. The position involves both research and teaching at the undergraduate and graduate levels. Applicants must have a doctoral degree in Electrical Engineering, an outstanding academic record and effective teaching ability. The position is supported by Bell Northern Research/Northern Telecom Ltd. with whom active interaction is expected. Additional research support may be available through the Natural Sciences and Engineering Research Council of Canada (NSERC) Research Partnerships Program. Salary is commensurate with qualifications and experience. Applicants should send a curriculum vitae, a statement concerning teaching and research interests, and a list of three references by January 31, 1995 to Professor Safwat G. Zaky, Chair, Department of Electrical and Computer Engineering, University of Toronto, Toronto, Ontario M5S 1A4, Canada. The Appointment will be made as soon as possible after the closure date. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. The University of Toronto is committed to employment equity and encourages applications from women, visible minorities, aboriginal people and physically challenged persons.

Memorial University of Newfoundland, Electrical Engineering: Applications are invited for ■ tenure-track position in Electrical Engineering at the Assistant Professor rank in the area of computer engineering with specialization in software engineering and preferred emphasis in real-time, object-oriented, parallel, or distributed systems. The successful applicant will be expected to teach undergraduate and graduate courses, conduct research, and participate in other educational, scholarly and professional activities. Applicants must have ■ Ph.D. in Electrical/Computer Engineering and have ■ demonstrated ability or potential to complement and expand the existing areas of expertise at Memorial University. Industrial and/or teaching and research experience is desirable. The successful candidate is expected to have or seek professional registration with the Association of Professional Engineers and Geoscientists of Newfoundland. The Electrical Engineering discipline has a well-established co-operative undergraduate program with a proposed undergraduate option in computer and communications engineering, as well as active graduate and research programs in applied electromagnetics, communications, signal processing, computer and digital systems, power systems, power electronics and control, and VLSI and microelectronics. The expected appointment date is April 1, 1995. Closing date for applications is December 31, 1994. Applicants should submit a curriculum vitae with the names of at least three referees, and three representative publications to: Dr. R. Seshadri, Dean, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X5 (Reference Elec-94-04). Fax #: (709) 737-8975. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents of Canada. Memorial University of Newfoundland is committed to employment equity.

University of Nebraska-Lincoln, Electrical Engineering anticipates one temporary and two tenure-track openings. The tenure track positions are in digital electronic circuits and in electronic devices and materials. Communication systems is preferred for the temporary position, but all areas of electrical engineering will be considered. Send letter of application, resume, list of three references with phone numbers and/or email addresses to Dr. R.J. Soukup, Chairman, Department of Electrical Engineering, University of Nebraska, Lincoln, NE 68588-0511. The selection process will begin 2/1/95. The University of Nebraska-Lincoln is committed to a pluralistic campus community through Affirmative Action and Equal Opportunity and is responsive to the needs of dual career couples. We assure reasonable accommodation under the Americans with Disabilities Act.

The University of California at Berkeley invites applications for tenure-track positions in Electrical Engineering and Computer Sciences beginning in Fall Semester 1995. We expect between one and four faculty positions pending final budgetary approval. Applications for appointments at the Assistant Professor level will be given highest preference, but other levels will also be considered. Applicants should have received (or be about to receive) a doctoral degree in Computer Science, Electrical Engineering, or Computer Engineering or a related field. All areas of research in Computer Science and Electrical Engineering will be considered. A principal requirement is demonstrated excellence in research. In addition, potential for excellence in teaching and leadership are important requirements. Successful applicants will be expected to set up a quality research program and to teach both graduate and undergraduate courses in their general area of specialty. Interested persons should send ■ resume, a select subset of papers, a one- to two-page statement of their future research plans and interests, and the names of three references by January 20, 1995, to the appropriate address below. In addition, the applicant should ask the three references to send letters directly to the same address. These letters will not be requested directly by the department. Applications submitted after the deadline will not be considered. Electrical Engineering Applications: Professor David Messerschmitt, Chair, Department of Electrical Engineering and Computer Sciences, 231 Cory Hall, University of California, Berkeley, California 94720-1770. Computer Science Applications: Professor Robert Wilensky, Associate Chair, Computer Science Division, 381 Soda Hall, University of California, Berkeley, CA 94720-1776. The University of California is an Equal Opportunity, Affirmative Action Employer.

The University of Southern California, Department of Electrical Engineering-Systems invites applications for several tenure track positions at all levels. Areas of interest include: computer/communication networks; mobile communications; automatic control; computer architecture and parallel processing; image processing and image understanding, statistical multidimensional and array signal processing, VLSI signal processing, digital signal processing (hardware and software); intelligent control (preferably with emphasis on intelligent vehicles and highways). Applications must include a comprehensive resume, ■ list of three to five professional references, and a letter of interest indicating clearly the position designated above for which you are applying. Senior level applicants should have demonstrated leadership ability in building a strong research program, and have a distinguished teaching and research record. Please send material to Chairman, EE-Systems Search Committee, EE-Systems Department, Los Angeles, CA 90089-2560. USC is an Affirmative Action/Equal Opportunity Employer and encourages and welcomes applications from women and minorities.

University of California, Davis, Faculty Positions in Electrical and Computer Engineering: The Department of Electrical and Computer Engineering at UC Davis invites applications for a tenure track faculty position at the Assistant Professor level. Applications are sought in the following three areas: (1) embedded computer systems including hardware/software co-design, application specific architectures and real time systems; (2) computer network design and implementation including network algorithms and protocols, high speed networks, high speed switches, network based parallel computing; and (3) optoelectronic devices with particular emphasis on experimental research in microfabrication and integration of hybrid optoelectronic systems. Truly exceptional senior candidates in above or related areas will also be considered. The department, with 31 faculty members and 145 full-time graduate students, is experiencing rapid growth. We have exceptional teaching and research facilities and have recently moved into a large, new building. Salary and benefits are extremely attractive. Davis is a pleasant, family-oriented community near Sacramento, within easy driving distance to Silicon Valley, the Lawrence Livermore National Laboratory, San Francisco, the Pacific Ocean. and the Sierra Nevada Mountains. We are seeking individuals with strong records in research, with ambitious plans and evidence of great promise. All faculty are expected to have ■ strong commitment to teaching at all degree levels, and to demonstrate the ability to attract significant research support. The positions require ■ Ph.D. degree or equivalent, and are open until filled; but in order to assure consideration, applications should be received by March 1, 1995. Send a resume and the names of at least three references to: Professor S. Louis Hakimi, Chair, Attention: Faculty Search Committee, Department of Electrical and Computer Engineering, University of California, Davis, CA 95616. The University of California, Davis and the Department of Electrical and Computer Engineering are interested in candidates who are committed to the highest standards of scholarship and professional activities and to the development of a campus

climate that supports equality and respect for differences based on gender, cultural ethnicity, level of disability, and sexual preference. The University of California is an affirmative action/equal opportunity employer.

The Department of Electrical Engineering at the University of Utah is seeking applications for an Assistant Professor or Associate Professor tenure-track faculty position. Applicants must have an earned doctorate or must expect to complete a doctoral program by September 1995. Duties of the successful candidate will include undergraduate and graduate teaching and development of a research program. The department has successful and well-funded research programs in electromagnetics, semiconductor materials and devices, communications, signal processing, optics, biomedical engineering, and microwave tubes. Special areas of interest for this recruitment are VLSI/microelectronics, MEMS, and digital electronics. Resumes and the names of three references should be sent to Professor Robert Huber, Electrical Engineering Department, 3280 Merrill Engineering Bldg., University of Utah, Salt Lake City, UT 84112. Please give visa status. Screening of applicants will begin November 1. Applications will be accepted until the position is filled. The University is an AA/EO employer and encourages applications from women and minorities, and provides reasonable accommodation to the known disabilities of applicants and employees.

Research Assistant to work in area of analog circuit design towards a Ph.D. degree. Funding is available. Please contact Dr. S. Embabi, Dept. of EE, Texas A&M University, College Station, Texas 77843-3128. Fax (409) 845-7161, e-mail: embabi@eemips.tamu.edu.

Applications are invited for the following posts: Department of Electronic Engineering: University Lecturers in the following areas: Mobile Communication and RF design, High Speed Networks, Fibre Optics, Telecom Software and Networking/Distributed Processing, Operating Systems and Concurrent Programming, Software Engineering, Data Structure and Data Base Management Systems, Functional and Object-Oriented Programming High Performance Computer Architecture/Intelligent Systems, Neural Networks and Fuzzy Theory/Modern DSP Applications, Speech/Digital TV and HDTV, Electronic Circuit and ASIC Design. The appointee will be required to teach up to post-graduate level and conduct research in one or more of the above-mentioned areas. Candidates are expected to have a PhD degree and a good record in research and publication, preferably with professional/teaching experience. Terms of Service: Initial appointments will be made on fixed term gratuity-bearing contract of two years at the end of which re-appointment is subject to mutual agreement. Other benefits include leave, medical and dental schemes, children's education allowance and subsidized housing where appropriate. Salaries: HK$412,980 p.a. - HK$468,480 p.a./BAR/HK$496,320 p.a. - HK$689,880 p.a. (Note US$1 = HK$7.73 approximately as of 19 September 1994). Applications: Send curriculum vitae and names of three referees to the Personnel Office, Hong Kong Polytechnic, Hung Hom, Kowloon, Hong Kong before November 21, 1994. [Fax (852) 364 2166], or by E-mail (BITNET HKPOLY@HKPCC.HKP.HK). Further information is available from the same office.

The Graduate Center for Biomedical Engineering of the University of Kentucky invites applications for a tenure-track position in the area of control theory and biomedical systems. Candidates should have a strong interest in graduate teaching and research. Preference will be given to applicants with research programs in functional electrical stimulation that will complement existing activities in neuromuscular control, biodynamics, and rehabilitative medicine. Appointment will be at the assistant professor level, or higher for an exceptional candidate. Submit a curriculum vitae with names of three references to: Search Committee, Center for Biomedical Engineering, Wenner Gren Research Laboratory, University of Kentucky, Lexington, KY 40506-0070. Applications accepted until the position is filled. Direct e-mail inquiries to bruce@bmel.image.uky.edu. The University of Kentucky is an equal opportunity/affirmative action employer. Women and minority persons are encouraged to apply.

Senior Engineering Faculty Position in Manufacturing Engineering: The University of California, San Diego, is establishing a new Program in World Class Manufacturing Engineering. This program will address both research and education of manufacturing for the next century. We are committed to developing an outstanding program to address the needs of our society. Our vision of this program emphasizes information engineering and international components of manufacturing. We believe that all aspects of manufacturing will be influenced by the emerging information infrastructure and this will result in making manufacturing an international operation. We need leaders to share our vision and shape this new program. The Schools of Engineering and International Relations and Pacific Studies (IR/PS) have been awarded ARPA funding for a new interdisciplinary master of science program in manufacturing engineering. Our new program in manufacturing engineering will begin with this seed funding. Candidates should have demonstrated leadership in manufacturing research and program development. A track record in making strong contacts with industry is required, while international connections are desirable. This is a tenured full professor level appointment. The home department can be any School of Engineering department depending on the research interests of the candidate. Responsibilities will include developing and directing the M.S. program, teaching and supervision of graduate students, establishing connections with industry for internships and adjunct faculty, and establishing strong funded research programs, including the Ph.D. level. Candidates with a senior background in industry and a Ph.D. are encouraged to apply. Salary commensurate with qualifications and experience and is based on University of California pay scales. Applications received by December 1, 1994, or thereafter until position is filled, will receive thorough consideration. Send detailed curriculum vitae and names/addresses of five references to Search Committee, c/o Vivian Shinmoto, School of Engineering, University of California, San Diego, Department 0043, La Jolla, CA 92093-0043. University of California, San Diego, is an equal opportunity/affirmative action employer.

University of California at Santa Barbara, Department of Electrical and Computer Engineering. Applications are invited for an open-level (tenured or tenure-track) position in the area of computer networks, available effective 7/1/95. Normally, completion of a doctorate is required at the time of the appointment. Established research reputation or outstanding research potential in communication network engineering and computer engineering is required, along with the ability to attract extramural research funding and a strong commitment to teaching at the undergraduate and graduate levels. Experience in high-speed digital electronics is also desired. Among senior applicants, we look for a distinguished scientist of international stature and a leader to help direct a rapidly developing research group into a position of national preeminence. Junior applicants must show exceptional promise of scientific distinction and leadership. Send a resume and the names and addresses of at least four professional references to: Faculty Search Committee, ECE Department, University of California, Santa Barbara, CA 93106-9560. Applications will be accepted until the position is filled. UCSB is an Equal Opportunity/Affirmative Action employer.

Kansas State University, Electrical and Computer Engineering Department, Faculty Position in Computer Engineering: The Department of Electrical and Computer Engineering at Kansas State University invites applications for a tenure track position in computer engineering at the rank of Assistant Professor. Applications of highly qualified candidates with an earned doctorate will be considered. Good written and verbal communication skills are essential. Candidates should expect to teach undergraduate and graduate Computer Engineering courses, advise M.S. and Ph.D. students, conduct research and attract funding in their field of specialization. Applications in all areas of computer engineering will be considered. However, preference will be given to applicants in the areas of Digital Electronics, Architecture, and Networking. A record of publications or demonstrated potential for independent research is necessary. The position is available for Fall 1995. Send a letter of application, resume, email address, and a list of three professional references to David L. Soldan, Head, Department of Electrical and Computer Engineering, 261 Durland Hall; Kansas State University, Manhattan, KS 66506-5105. Applications will be reviewed starting January 15, 1995. KSU is an equal opportunity/affirmative action employer.

Iowa State University: The Department of Electrical and Computer Engineering invites applications for several tenure-track faculty positions. Applicants at all ranks will be considered. Starting dates are negotiable with preference given for Spring 1995 and Fall 1995. Primary needs are for specialization in the areas of analog VLSI, communications, signal processing, computer networks, distributed computing, real-time systems, electromagnetics, and microelectronics. Responsibilities include teaching, research and outreach. Salary and rank are commensurate with qualifications and experience. Requirements include a doctorate degree with a demonstrated potential for success in research and teaching. Applicants should send a resume with a statement of teaching, research, and outreach interests, as well as a list of three (3) references to: Chair, Faculty Search Committee, Department of Electrical and Computer Engineering, Iowa State University, Ames, Iowa 50011. Interviews will commence after December 1, 1994. Iowa State University is an Equal Opportunity/ Affirmative Action Employer.

Faculty Position in Electrical Engineering: The University of West Florida (UWF) in cooperation with the University of Florida (UF) has established a cooperative program in Electrical Engineering on the UWF campus in Pensacola which will lead to a UF degree. Applications are invited for two tenure-track, nine month positions with rank of Assistant Professor. A doctorate in E.E. is required and the qualifications to teach undergraduates in either digital signal processing or power systems. In addition, the applicant must be qualified to support teaching in one of the following areas: communication systems, computer engineering, or control systems. Preferential consideration given to candidates with U.S. undergraduate E.E. education, appropriate teaching experience, and/or a professional engineering license. Letter of application listing three professional references, copies of both undergraduate and graduate transcripts, and a complete resume should be sent to Dr. Ronald C. Houts, UF/UWF Joint Program in E.E., College of Science and Technology, The University of West Florida, 11000 University Parkway, Pensacola, FL 32514-5750. Starting date negotiable. Salary range $42,000 to $48,000. Application deadline is January 8, 1995. UWF is an Equal Opportunity Access/ Affirmative Action Employer. Women and minorities are encouraged to apply.

Department Head, Electrical and Computer Engineering: The Air Force Institute of Technology Graduate School of Engineering invites applications for the position of Head of the Department of Electrical and Computer Engineering. The Department has over 175 full-time graduate students 35 of which are at the PhD level pursuing degrees in electrical engineering, computer engineering and computer science. The Department has thirty-six faculty teaching and doing research in a wide variety of areas. The Department Head will be expected to provide leadership to the faculty in teaching and research. Candidates should hold an earned Doctorate in Electrical or Computer Engineering or in a closely related field. He/She must be a U.S. citizen and have a strong record of teaching and publication commensurate with appointment at the rank of Professor. Applications will be accepted immediately and until the position is filled.

Applicants should send a resume and the names of three references to: Dr. Robert A. Calico Jr., Dean, Graduate School of Engineering, Air Force Institute of Technology, 2950 P Street, Wright Patterson AFB, Ohio 45433. The Air Force Institute of Technology is an Equal Opportunity/Affirmative Action Employer.

The University of New Hampshire, Department of Electrical and Computer Engineering invites applications for a tenure-track appointment at the Assistant Professor level beginning September, 1995. Applicants must have ■ Ph.D. degree in electrical or computer engineering and a commitment to both research and teaching. The successful candidate will have a background and interests related to the electronics of high performance data communications, and a desire to develop related advanced coursework. The ECE Department has thirteen tenure-track faculty and offers programs leading to the BS, MS and PhD degrees. The selected candidate will have the opportunity to work closely with the University's Interoperability Laboratory. This interdisciplinary laboratory performs collaborative R&D and provides interoperability evaluation for member companies organized in several consortia focused on specific network technologies. The University is a Land Grant, Sea Grant, and Space Grant university with approximately 12,400 undergraduate and graduate students. It is located near the New Hampshire seacoast and is within sixty miles of Boston, Portland and the lakes and mountains regions of New Hampshire. Applicants should send full resumes and names of at least three references to W. Thomas Miller, III, Chairman, ECE Department, Kingsbury Hall, UNH, Durham, NH 03824. Review of applications will begin January 9, 1995, and will continue until the position is filled. Women and minorities are encouraged to apply. UNH is an AA/EEO Employer.

Department of Mathematics and Statistics, Queen's University at Kingston: The Department will be making a renewable (tenure-track) appointment in Applied Mathematics at the Assistant or possibly Associate Professor level to begin July 1995. Membership or eligibility for membership in a Canadian professional engineering association is required. The Department is particularly interested in applicants in communications theory, information theory or fluid mechanics, but other areas will be considered. The successful applicant will have ■ strong research record, be expected to develop an independent research programme, be willing and competent to teach a broad range of applied mathematics courses, and supervise graduate students. Interested candidates should arrange that a curriculum vitae, ■ description of teaching and research interests, at least three letters of recommendation, and copies of their three most significant publications arrive at the address below before January 15, 1995. At least one letter should comment on the candidate's teaching. Professor Leslie Roberts, Associate Head, Department of Mathematics and Statistics, Queen's University, Kingston, Ontario K7L 3N6. Queen's University has an employment equity programme and encourages applications from all qualified candidates, including women, aboriginal peoples, people with disabilities and visible minorities.

Chairperson, Department of Electrical Engineering, University of Maryland at College Park. Applications and nominations are invited for the position of Professor and Chairperson of the Department of Electrical Engineering. The University of Maryland is an equal opportunity affirmative action employer. Women and minority candidates are particularly encouraged to apply. Candidates should have an earned doctorate in electrical engineering or a closely related field, strong leadership ability, a proven research record, and a commitment to electrical engineering education. The Department of Electrical Engineering consists of 61 full time faculty and a number of research associates and lecturers. The faculty includes 32 Fellows of the IEEE and the American Physical Society and 11 Presidential Young Investigator Award recipients. The Department awards approximately 45 Ph.D., 70 M.S. and 200 B.S. degrees annually. The research expenditures by the department are in excess of $14M per year in areas including communication and signal processing, computers, controls, electrophysics and microelectronics. The department plays a major role in the Institute for Systems Research, a NASA Center for Satellite and Hybrid Communication Network, the Institute for Plasma Research and the University of Maryland Institute for Advanced Computer Studies. Applications should include a complete curriculum vitae and names of references. Applications and nominations should be sent to: Professor Aris Christou, Chair, E.E. Department Chair Search Committee, Department of Materials and Nuclear Engineering, University of Maryland, College Park, Maryland 20742-2115. For best consideration, applications should be received prior to January 15, 1995. The University of Maryland is an equal opportunity affirmative action employer.

Chair, Department of Electrical Engineering: The joint College of Engineering at Florida A&M University and Florida State University invites applications for the position of Chair, Department of Electrical Engineering effective Fall 1995. Candidates must have a Ph.D. degree in electrical engineering, be eligible for tenure at the rank of full professor, and have administrative skills to manage a program offering bachelor, masters and Ph.D. degrees. Qualified persons should submit letters of application, a statement of academic and administrative philosophy emphasizing their ability to foster faculty and research development; a resume showing evidence of research, administrative and teaching skills, names, addresses and phone numbers of five references to Dr. J. Willard Toliver, Associate Dean, FAMU/FSU College of Engineering, P.O. Box 2175, Tallahassee, Florida 32316-2175. Applications and nominations will be accepted until February 1, 1995. The department is strongly oriented towards research and quality education for undergraduates and graduates and consists of 16 faculty and 5 staff members. The program is accredited by ABET and has an enrollment of 600 students with approximately fifty percent being African Americans and twenty-five percent women. The FAMU/FSU College of Engineering welcomes applications and nominations of women, minorities and persons with disabilities.

Faculty Positions, Biomedical Engineering, Louisiana Tech University: The Biomedical Engineering Department at Louisiana Tech University invites applications for two tenure-track positions: Senior Researcher at Associate Professor or Professor rank: Seeking experienced researcher with focus on biomedical applications of microsensors/microdevices. Candidates must have demonstrated the ability to establish and sustain an externally funded research program and supervise graduate-student research. Limited teaching responsibilities in specialty area. Opportunity to interact with staff and facilities of Louisiana Tech University Institute for Micromanufacturing and LSU School of Medicine in Shreveport. Associate or Assistant Professor: Applicants will be expected to teach undergraduate/graduate courses (including physiological control systems) and direct graduate-student research. Candidates must have demonstrated the ability to establish an externally funded research program. Teaching experience is preferred. The Biomedical Engineering Department offers a nationally-recognized academic program with emphasis on systems physiology and rehabilitation engineering. Degrees are offered at the B.S. (ABET-accredited), M.S. and Ph.D levels with an enrollment of over 175 undergraduate and 35 graduate students. The Department's Board of Regents-funded Center for Rehabilitation Science and Biomedical Engineering provides opportunities for professional growth and for interactions with the LSU School of Medicine in Shreveport and the University's Institute for Micromanufacturing. The University is developing world-class resources for development of microstructures, devices and systems. Candidates for either position must have earned a doctorate in Biomedical Engineering or a related field, and be US citizen/permanent resident. Preference will be given to candidates with strong background in animal experimentation and systems physiology. Send curriculum vitae, statement of teaching and research interests/goals, and names and addresses of at least three references to Dr. Stan A. Napper, Chair of Search Committee, Biomedical Engineering Department, Louisiana Tech University, P.O. Box 10348, Ruston, Louisiana 71272 (phone 318-257-2645, Fax 318-255-4175, e-mail san@engr.latech.edu). Applications will be reviewed starting February 1, 1995; positions are available September 1, 1995. Louisiana Tech University is an equal employment university. Women and minorities are encouraged to apply.

Assistant Professorships available in Electrical Engineering Technology (Power), and Electrical Engineering Technology (Control Systems). A doctorate in Engineering three to five years related industrial experience, and a record of effective teaching and scholarship required for a tenure track position. The application period ends December 1, 1994. Starting date is September 1, 1995. Women and minorities are encouraged to apply. Send application, vita and three references to: Dr. Charles Beasley, Chair, Department of Technology, SUNY/College at Buffalo, 1300 Elmwood Avenue, UH 314, Buffalo, NY 14222-1095. SUNY/College at Buffalo is an equal opportunity employer.

Faculty Position: The Electrical Engineering Department at the University of Massachusetts Lowell has successfully established ■ Master's degree in Computer Engineering, as well as Bachelor's, Master's and Doctoral programs with a concentration in Digital Circuits, Systems and Computers. Half of the department's graduate students are now enrolled in these programs, students being both full and part-time, with a significant number coming from large companies in the greater Boston area. The area of advanced digital systems is crucial to the region's manufacturing sector and we expect continued growth in the number of students demanding these courses and research opportunities. We are seeking a new faculty person to form the nucleus of these programs and research activities and to develop them further. Applications are sought from those with established research programs and expertise in this area. The successful candidate will also be expected to maintain a strong research activity; ■ proven record of publications, funding and strong track record in working with industry is expected. The appointment will be tenure track, with academic rank commensurate with experience. Candidates should submit a curriculum vitae, statement of research interests, reprints of significant publications and names of three references to: Dr. Michael A. Fiddy, Department Head, Department of Electrical Engineering, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854; (508) 934-3300; Fax (908) 934-3027; fiddy@cae.uml.edu Candidates are encouraged to submit promptly, but applications will be accepted until the position is filled. The availability of the position is contingent upon funding. The University of Massachusetts Lowell is an equal opportunity/affirmative action, Title IX, H/V, ADA 1990 employer.

San Jose State University, Electrical Engineering Department: Applications are invited for ■ tenure-track faculty position. Assistant Professor applicants are particularly encouraged to apply. The position is available in microelectronic VLSI/ULSI circuit design, semiconductor devices and technologies. Earned doctorate in Electrical Engineering is required. The position is limited to U.S. citizens or permanent residents. Research, consulting and summer employment opportunities are available. The University is the oldest and one of the largest in the California State University System. It is located at the southern end of San Francisco Bay in the heart of Silicon Valley. Resume and names and addresses of three references should be submitted to Dr. Ray R. Chen, Chair, Department of Electrical Engineering, San Jose State University, San Jose, CA 95192-0084. San Jose State University is an equal opportunity/affirmative action/Title IX employer. Women and minorities are especially encouraged to apply.

Industrial Research Chair in Instrumentation and Control: The Natural Sciences and Engineering Research Council of Canada (NSERC) has approved funding for two Industrial Research Chairs in Advanced Instrumentation and Control at the University of New Brunswick, one

Senior and one Junior. The industrial partners are Monenco AGRA, a major international contractor for large-scale turn-key systems most of which require instrumentation and controls, and Elsag Bailey, a world-wide vendor of controls hardware and software. The Senior Chair has been filled by Dr. James H. Taylor, formerly of GE Corporate R&D and Odyssey Research Associates. A tenure-track position is open for the Junior Chair, in either the Chemical, Electrical or Mechanical Engineering Department depending on the interests and background of the chosen individual. High academic qualifications, industrial experience and willingness to collaborate with industry and other engineering faculty will be major factors in candidate selection. Transfer of technology to industry will also be an important goal. Resources for collaboration include on-going research programs in performance monitoring and fault diagnosis, smart sensors and actuators, real-time data acquisition, modeling and simulation, robust control design, nonlinear control and optimization, and computer-aided control engineering, The University also has related research in its centres for microelectronics, manufacturing, and nuclear energy, and cooperation will be encouraged with existing Chairs in Nuclear Engineering, Pulping Technology and Power Plant Engineering. Candidates must have a PhD with a strong applied research background in control and instrumentation, and should be eligible for registration as Professional Engineer. Interest and expertise in instrumentation, signal processing and digital implementation (including fault-tolerant design) will be advantageous, in addition to a solid systems and controls background, preferably in mechanical or process applications. The University of New Brunswick is committed to the principle of employment equity. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens or permanent residents. The closing date for nominations and applications is 31 December 1994 or until the position is filled. Nominations, applications and requests for information should be forwarded to: Dr. Wolfgang Faig, Dean, Faculty of Engineering, University of New Brunswick, PO Box 4400, Fredericton, NB CANADA E3B 5A3. (506) 453-4570.

Government/Industry Positions Open

Senior Development Engineer for firm in NE Ohio. Participate in the following projects: perform a computer simulation of Jet-Flow channel inductor; develop a reliable three-dimensional numerical model for the channel furnace; and develop computer programs for power distribution calculations in transverse flux induction heating. Must have Ph.D. in Electrical Engineering. Academic program must have included one graduate-level course each in the following areas: Nonlinear Circuits, Special Topics in Power Fields, Approximate Methods Applied to Field Problems, Electro-Heat Process, Special Topics in Power Fields II, and Power Conversion II. Must be able to perform electromagnetic field modeling and computation by using finite difference method, finite element method, boundary element method, and volume integral method. Must also be able to perform electromagnetic field calculations of two-dimensional multi-layer cylindrical geometrics by using transfer matrix method. Must be conversant with magnetohydrodynamics, electromagnetic stirring in continuous casting, and electromagnetic stirring in coreless induction furnaces. These skills may be evidenced by academic letter(s) of reference and/or employer(s) testimonial(s). Must have 2 yrs exp in Electrica-Research Engineering. Exp must be in Electromagnetic Field Modeling and Computation. 40 hrs/wk, 8:00am-5:00pm, $54,900/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume & course transcript in duplicate (No Calls) to T. Do, Job# 00560, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Electrical Design Engineer (DSP) - Conceive, design & evaluate circuits for new product development in the field of Digital Signal Processing (DSP), focusing on the development of filtered parallel IIR adaptive noise cancellation (ANC) systems & components & their incorporation into new & existing DSP packages. Develop, test & refine new circuits & components. Use DSP principles & methodology to perform system modeling & optimization & to meet quality, cost performance & schedule goals. Perform UNIX shell programming & "C" programming, utilizing DSP analysis tools (Matlabs & ILS) within UNIX & Windows environments on SUN/sparc stations. Conduct independent research & development. Prepare written reports of research & present research findings to department management & at professional conferences. Establish technological requirements. Design & implement DSP algorithms. Simulate, analyze & conduct performance & parameter optimization. Investigate system tradeoffs & verify the final performance to specification. 40 hrs/wk, 9am to 5pm. $41,500/yr. Must have 5 years of college & M.S. degree in Electrical Engineering, and have completed at least 1 graduate-level course each in: 1) Digital Signal Processing, 2) Advanced Digital Signal Processing, 3) Digital Processing of Speech, 4) Discrete Time Systems, 5) Digital Communications, 6) Switching Theory, and 7) Coding Theory. Must have had at least 3 papers published in professional journals, 2 of which must specifically address issues in the field of adaptive noise cancellation. Must have 2 years experience in the job offered or as Graduate Research Assistant. Experience as Graduate Research Assistant must be in the field of telecommunications and/or digital signal processing & must include at least 1 year of research on the development of filtered parallel IIR ANC systems, involving use of UNIX shell programming, "C" language programming, DSP analysis tools (Matlabs & ILS), UNIX & Windows environments, & SUN/sparc stations. Must have proof of legal authority to work permanently in the U.S. Send resume to: Illinois Department of Employment Security, 401 South State Street - 3 South, Chicago, IL 60605, Attn: Dennis Jones, Ref# V-IL 11915-0. No Calls. An Employer Paid Ad - Send 2 Copies of Resume.

Electrical Engineer: Responsibilities include bench testing of NVH materials, developing software to automate all testing in the acoustic lab including dynamometer tests. This automation will also require the development of a database to log all measurement results. Responsible for the development of advanced analysis and measurement techniques including acoustic modeling techniques. Salary, $42,900 per year, 40 hour week (8:00 - 5:00). Requirements, Masters degree in Electrical Engineering. Must have completed one graduate level course in the following area - Communications Systems; Antenna Theory; Random Variables/Processing; Digital Signal Processing; Adaptive Signal Processing; Information Theory. Send resume to: MESC, 7310 Woodward Ave., Rm. 415 (Ref. #102494) Detroit, MI 48202. Employer paid ad.

Software Engineer needed to perform design/modif. of high-end software product line & demos; incl. writing specs, code, testing & debug. applications to assure error free software; consult w/other software engs., marketing dept. & customers to develop product enhancements in US & abroad. Travel abroad req'd (Europe/Austral.), employer pd. Must Have: B.S. or equiv. in Comp. Sci. or Electrical Eng. w/major/specializ. in mathematics; + 5 yrs exper. as software eng. w/ high-end software develop. incl. C lang., Windows develop., Windows Graphical Device Interface, visual design (icons/bitmaps) & w/computer based training packages for tutorials; + 1 yr exper. designing products in Europ. or Austral. mkts. Exper. may be gained concurrently. $48,000/yr, 40hrs/wk, Kirkland, WA. Send resume by 11/28/94 to: Employment Security: Job #451650, P.O. Box 9046, Olympia, WA 98507-9046.

Applications Engineer: To work for Central Ohio mfg of process control systems. Responsible for engineering (design, development, implementation and commissioning) of the MOD300 for batch or continuous applications to the chemical (surfactance or polyethylene or fertilizer) industries. Works closely with manufacturing and customers engineering staff to ensure project is completed within budget, scope, and schedules. Principal Duties: 1) Develops clear understanding of job requirements and specifications, customer product and processes to be controlled. 2) Develops time tables, schedules and costs of all tasks necessary to complete system within budget and schedules. 3) Assigns project tasks to team members, monitors and coordinates their assigned duties. 4) Designs and develops total engineering of project including hardware and system software. 5) Coordinates with manufacturing manager on manufacture of system in accordance with delivery schedules and production cycle. 6) Periodically reviews and monitors cost of project and time tables to insure system is completed within budget and time tables; confers with applications manager on progress of project. 7) Confers with and advises customer engineering staff on progress of project. 8) Develops start up plan, performs start up and secure commissioning and formal acceptance of system by customer engineering staff including demonstration that system meets job specifications and stated requirements. Must have BS in EE or foreign equivalent (degree determined equivalent by a credentials evaluation agency). Must have 3 yrs exp. in job offered or related occupations of applications engineer or instrumentation engineer. As part of reg. exp., must have supervised or engineered (designed, developed, implemented & commissioned) process applications for A) 6 batch projects (each: 5 nodes, 1000 regulatory I/O & 100 control loops), 3 of which must be flexible batch systems monitoring 5 differ. processes or B) 2 continuous projects (each 10 nodes, 2500 I/O &100 control loops). C) All projects must be on MOD300 for chemical applications. Travel 30/40%, aver. trip 1-2 wks, 90% out of state. Salary: $46,000. 40 hrs/wk. (Mon-Fri, 8AM-5PM). Must have proof of legal authority to work indefinitely in U.S. Send resume in duplicate (no calls) to J. Davies, Job #00510, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Software Engineer: Develop circuits w/in Chipcrafter environment to generate process-independent or process-migratable geometry, utilization of CDS, SPICE circuit simulator, schematic editor, & Verilog simulator. Translate netlists into Chipcrafter environment to produce functionally equivalent circuitry using Chipcrafter standard cells, & layout verification software to perform LVS, DRC, & ERC checks to verify circuit geometry. Requires: BS in EE, w/20 credit hours in digital & VLSI design. 1 yr exp in circuit design, incl use of Chipcrafter Design automation tool, CDS, UNIX, Verilog, SPICE, Cadence LVS/DRC/ERC tools & Virtuoso & Construct layout editors, & CMOS process & architecture. $37,750 to $53,000/yr, DOE; 40 hrs/wk in Bellevue, WA. Send resume by 12/2/94 to: Job Order #448990, Employment Security Department, E & T Division, P.O. Box 9046, Olympia, WA 98507-9046.

Software Design Engineer, by December 1, 1994, please send resume to: Employment Security Department, E&T Division, Job # 451304-J, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Designs, implements and tests software for micro computers following standard procedures. Designs and implements graphical administration and other front end tools for accessing database engine products. Utilizes "C", "C++" and SQL programming languages, Windows operating system, and multithreaded operating systems. Requirements: Bachelor's degree in Electrical Engineering, Computer Science, Mathematics or Physics; One year of work experience in designing and implementing (1) database management system software and (2) object oriented software in "C" language to run on Windows operating system, including graphical user interface controls. Experience must include six months work or semester long or equivalent school thesis project experience in (1) programming or computer software design utilizing SQL language and (2) design and implementation of software to run on a multithreaded op-

erating system. Experience may be gained concurrently. Must have legal authority to work in the United States. Job location: Seattle area employer. Salary: $42,000-$50,000 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE. Cover letter/resume must reflect all requirements.

Software Design Engineer, by December 1, 1994, please send resume to: Employment Security Department, E&T Division, Job # 452198-S, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Designs, implements and tests software for micro computers under limited supervision. Designs, implements, and integrates transport layer networking components of advanced multitasking/multithreaded operating systems and analyzes and improves performance of such components utilizing Windows NT operating system and "C" and 86 Series Assembler, Alpha and MIPS assembly languages, and streams environment. Requirements: Master's degree in Electrical Engineering, Computer Science, Mathematics or Physics; Two years of work experience in designing and implementing transport (NetBEUI, IPX or TCP/IP), datalink, and file server networking software under streams environment, to include six months of work experience or minimum of semester long or equivalent school thesis project experience or graduate school course project (minimum 3,000 lines of code) in programming or computer software design utilizing "C" and assembly languages; and programming software to run on a multithreaded/multitasking operating system. Experience may be gained concurrently. Must have legal authority to work in the United States. Job location: Seattle area employer. Salary: $46,000-$55,000 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE. Cover letter/resume must reflect all requirements.

Software Development Manager, by December 1, 1994, please send resume to: Employment Security Department, E&T Division, Job # 452025-Z, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Manages software development teams engaged in designing and implementing real-time multitasking operating system software for personal computers, intelligent fax machines, and intelligent copiers, including communications software. Leads technical aspect of relationship with original equipment manufacturers and independent software vendors concerning requirements and specifications for the digital office equipment and its software interfaces. Utilizes "C" and X86 Series Assembler programming languages, and multitasking/multithreaded operating systems. Supervises 17 engineers, including technical leads. Requirements: Bachelor's degree in Electrical Engineering, Computer Science, or Mathematics; six years of work experience in designing and implementing real-time multitasking operating system software for personal computers with Intel architecture. Experience must include two years of experience managing people; project management of at least two products from conception through commercial release; two years of work experience in working with original equipment manufacturers and independent software vendors to specify hardware requirements and software interfaces; and two years of work experience in designing and programming software utilizing "C" and X86 Series Assembly languages. Experience may be gained concurrently. Must have legal authority to work in the United States. Job location: Seattle area employer. Salary: $65,500-$88,000 per annum, depending on experience. Compensation package includes bonuses and stock options. 40 hours per week, flex time. EOE. Cover letter/resume must reflect all requirements.

Computer Applications Engineer to design and implement a framework for the electrical design process and to provide process management and data management strategies for analog and digital product design utilizing integrated circuits; configure and setup electrical design (CAD) tools like POWERVIEW, VISULA, and CAE modeling and simulation tools like Saber, Verilog, Precise, and Verimix; build seamless interfaces between the CAD and the CAE tools; build custom libraries for these tools in C and FORTRAN languages; build custom user interfaces for these tools in C language and X Windows/Motif for HP Workstations; configure and administer design and data management software PowerviewDM, Encapsulate ECAD/CAE tools into Powerview DM. Require Master's in Elec. Eng. Related coursework must include Computer Modeling and Simulation, Very Large Scale Integrated Circuits Design, and Programming Languages. Must provide Master's Thesis utilizing Computer Modeling of Integrated Circuits using UNIX Workstations, C and FORTRAN languages. 40 hr. wk. 8am-5pm. $43,200/yr. Send resume to 7310 Woodward Avenue, Room 415, Detroit, Michigan 48202. Ref. No. 105794. Employer Paid Ad.

SW developer: Dev. gate/transistor simul tools. Automate opt. of statistical delay/power. Extract gates from transistor netlist. Knlg of BiCMOS gate/transistor modeling, statistical analy and opt, pattern matching, ASIC cell design. Pgm in C/shell/openlook. $5583/month. PhD in EE/CS+3 yrs exp in CAD system dev and pf to work in US permanently are required. Send resume to IEEE Spectrum, Box 11-1, 345 E. 47th St., New York, NY 10017.

System Software Engineer: To work for software consulting firm located in Central Ohio. Position Objective: To provide total testing support to test integrity of software written in C language on UNIX and developed for telecommunications (CCITT SS7/CCS7) applications. Enhancement and development of test software. Position Duties: 1) Familiarization, including documentation, of modules to be tested, including system level requirements and functionality. 2) Identification of required test utilizing cause, effect techniques, and development of data and messages to be included in test. 3) Development, using Sun workstation of automated test software, including confirmation of integrity of test software, troubleshooting of functional test configurations and development of documentation. 4) Execution of test to validate software integrity and confirmation that software meets features and performance requirements. Analysis of test results to identify software problems and creation of software modifications requests to insure compliance with system requirements and specifications. 5) Execution of additional testing incorporating software modifications. 6) Development and enhancement of testing standards and methodologies, and testing tools to validate present and future system features. Must have an MS in E.E. with specialization in communications or MS in computer science with specialization in networking, no experience required, or BS in EE or CS and two years of experience in Job offered or related occupation of system software engineer. Requirements below may have been gained concurrently. Must have A) written a minimum of 2000 lines of C code on UNIX. B) Completed 2 projects in connection with 2 graduate or undergraduate level courses, 1 project developed on a Sun workstation, and 1 project developed on AT&T 3B2. C) 1 graduate or undergraduate level course in advanced telecommunications switching systems which included CCITT SS7 as one of the protocols. D) 1 graduate or undergraduate level course which included a project requiring functionality and performance testing of a software or hardware component. E) 2 graduate or undergraduate level courses in telecommunications, 1 of which included cellular mobile telecommunication technology and the other, telephone switching systems. Salary: $42,000. 40 hrs/wk. (Mon-Fri, 8AM-5PM). Must have proof of legal authority to work indefinitely in U.S. Send resume in duplicate (no calls) to: T. Do, Job Order #: 00597, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216. An Equal Opportunity Employer.

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Electronics-Design Engineer, Gaming; 40 hours/week; 9:00 a.m. - 6:00 p.m.; $43,000/year. Job requires: Master of Science degree in electrical or electronics engineering or computer science and 1 year, 6 months experience in Job Offered or as Software Engineer. Job also requires: Educational or work experience must have included electronic game design & secure communications protocols & random number generator analysis in context of games of chance; mathematical pay structure design & analysis & in-circuit emulation; & use of 80 x 86 Assembler & C++ languages in real time, object-oriented design for embedded systems. Job duties: Design, develop & implement electronic games of chance, including components & embedded systems for the video gaming devices. Analyze data on proposed products for design development. Perform in-circuit emulation of embedded systems & pay structure & random number generator analyses. Coordinate design implementation in gaming completion. Evaluate, modify as necessary electronic gaming performance. Interface directly with gaming certification laboratories & customers of products; provide customer support. Must have proof of legal authority to work permanently in the U.S. Qualified applicants should send resumes to Illinois Department of Employment Security, 401 South State Street - 3 South, Chicago, Illinois 60605, Attention: Dennis Jones. Refer to Job Order #V-IL 11731-0. No Calls. An Employer Paid Ad - Send 2 Copies of Resume.

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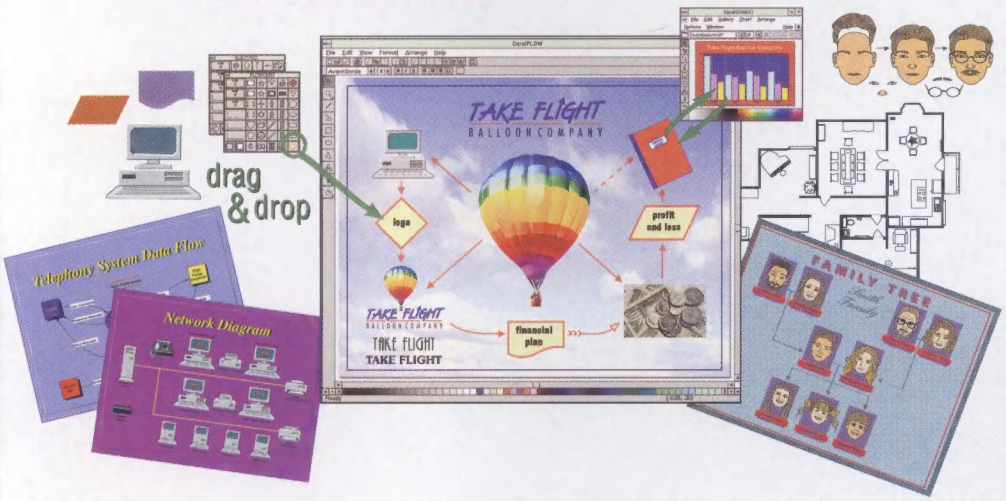
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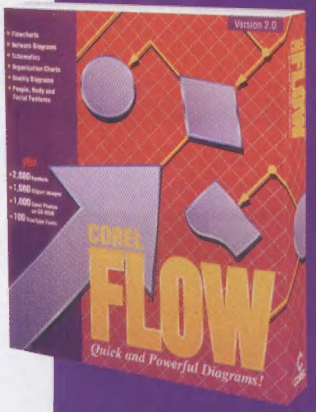
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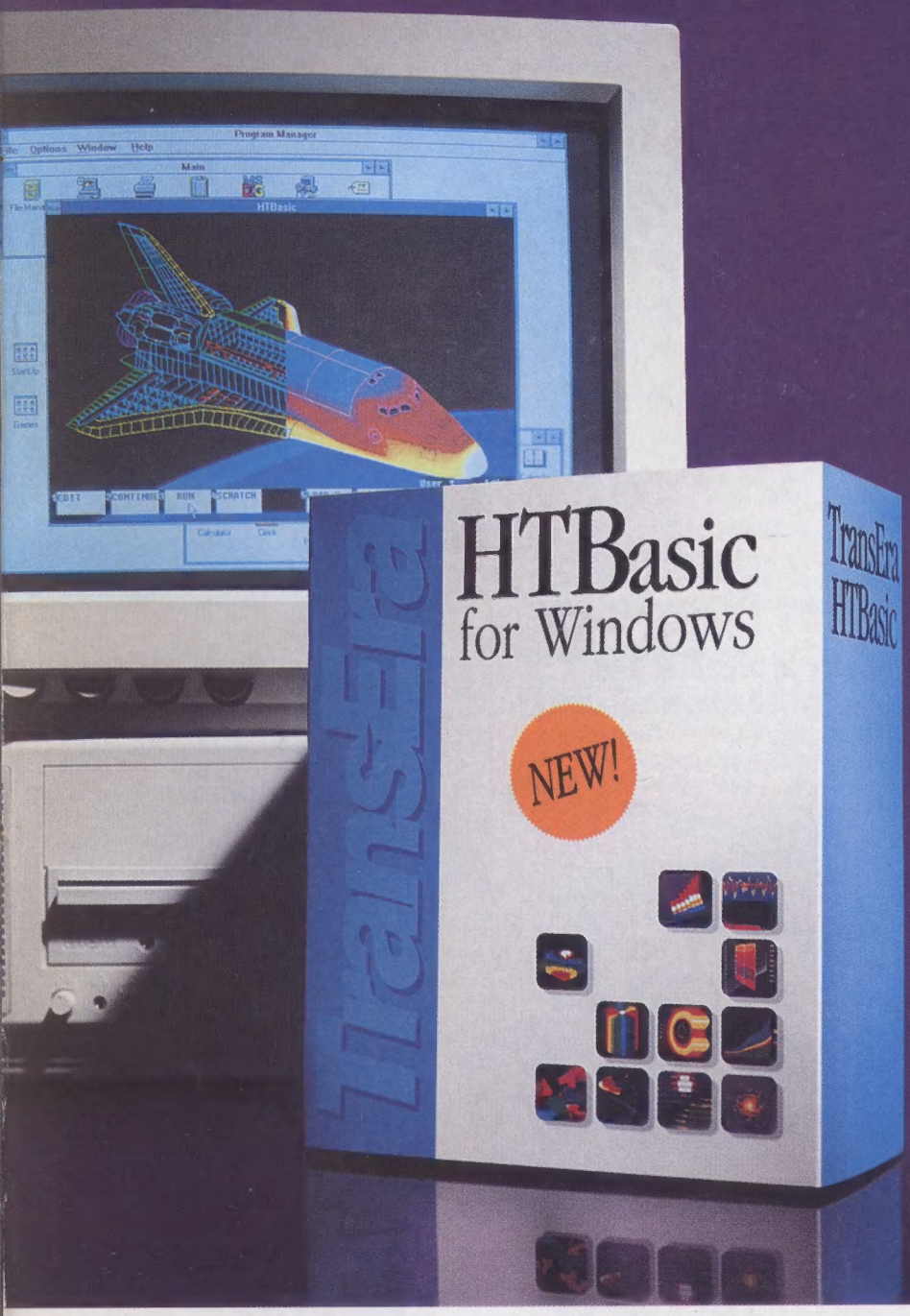
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